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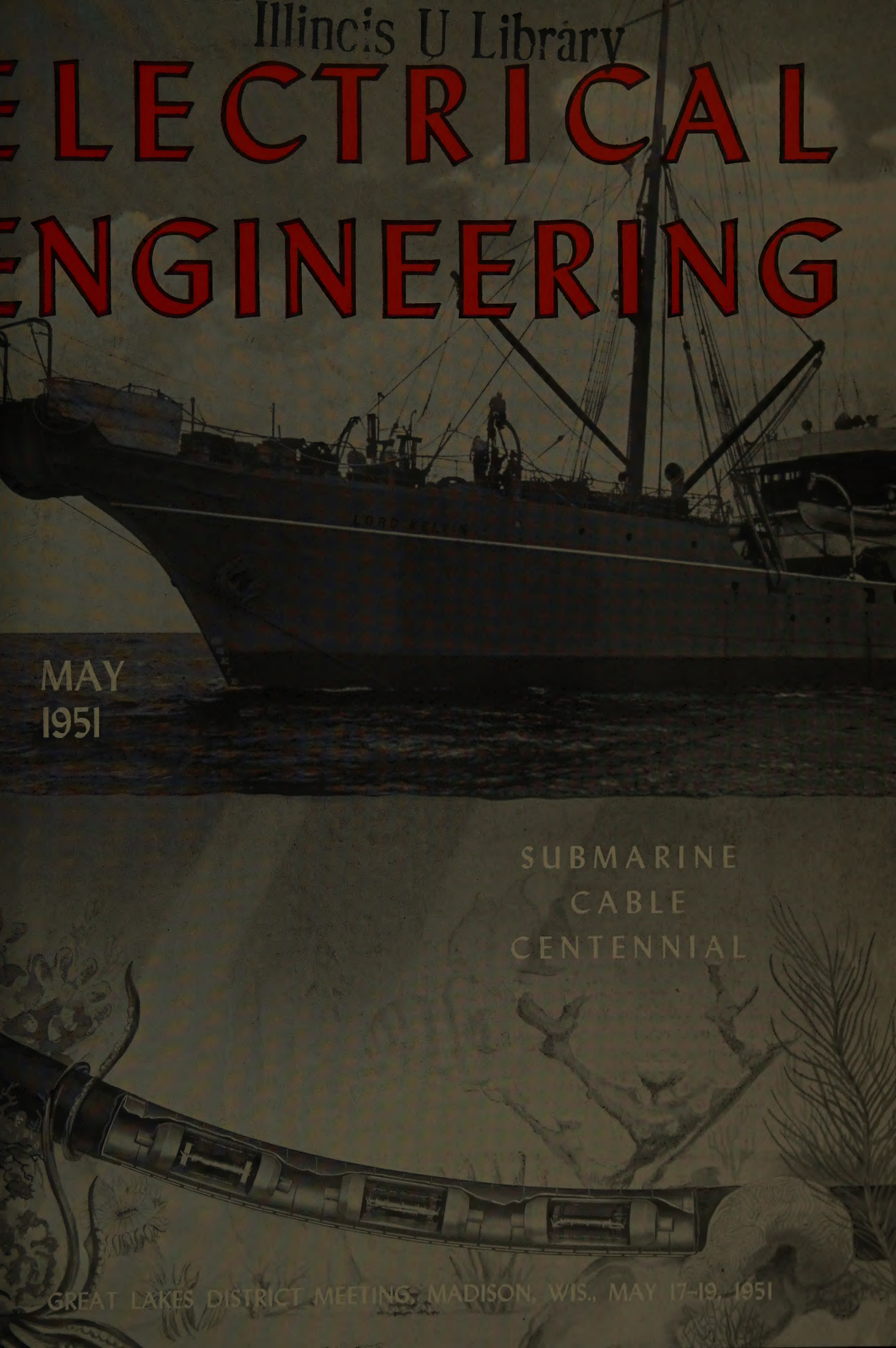
ELECTRICAL ENGINEERING



MAY
1951

SUBMARINE
CABLE
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GREAT LAKES DISTRICT MEETING, MADISON, WIS., MAY 17-19, 1951

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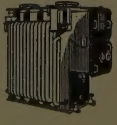

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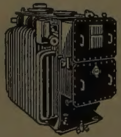

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MAY

1951

The Cover: The cable ship, *Lord Kelvin,* of the Western Union Telegraph Company, laid the cables for the Key West–Havana submarine telephone cable system. The bottom half of the cover shows the submerged repeater described in the article, "A Submarine Telephone Cable with Submerged Repeaters," by J. J. Gilbert (*EE, Mar '51, pp 248–53*).

Photograph courtesy Bell Telephone Laboratories

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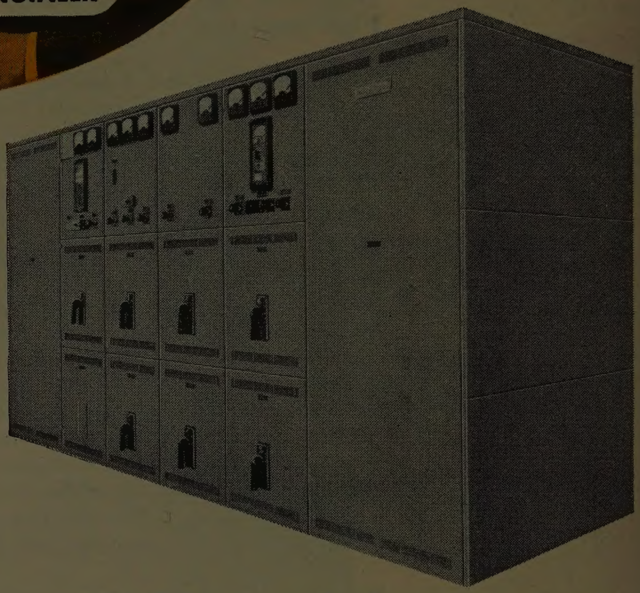
WHICH MAN IS THE EXPEDITER?



Customer, sales engineer, production manager — all three have a direct influence on the speed with which a switchgear order can be produced and delivered.

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HIGHLIGHTS........

at to Do About Shortage of Engineers? esident LeClair suggests three funda- ntal approaches to overcoming the oblem of the shortage of engineers in in- strial and military fields. Then he dis- sses ways of maintaining a continuing pply of engineers. Most important is at an engineer's time and talents not be sted in unproductive or nonengineering rk (*pages 377–78*).

e Genesis of Submarine Cables. oyd Espenschied of the Bell Telephone boratories, Inc., reviews the historical ents preceding the laying of the first sub- arine cable in 1851, and the subsequent velopments in the field of communica- ns (*pages 379–83*).

rcraft Navigation. Many of the instru- ents which are used to navigate an craft on domestic federal airways are interest to electrical engineers. The eas used in the design of these compact, ect-reading, accurate instruments are plicable to other fields (*pages 384–88*).

e Importance of Graduate Work in the wer Field. The power field has be- me so complex that a 4-year college pro- am in engineering is no longer adequate. raduate work or industrial training pro- ams are essential if the young engineers e going to be able to solve the problems the present and the future (*pages 391–93*).

rther Development of Fluid Mappers. this article, those who are building id mappers for teaching, research, or plication are assisted in understanding the nitations and in minimizing inherent ects tending to reduce accuracy. The merous problems and needs described ould invite interested workers—especially aduate students—to tackle the tasks that ll lead to better techniques, a broaden- g of the range of work to which map- rs may be applied, and an increase in the owledge required for designing fluid appers for specific jobs (*pages 396–401*).

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Automatic Teletypewriter System. Important features of the full automatic private line teletypewriter switching system are the arrangements provided to permit efficient use of long, full duplex transmission lines, the fully automatic handling o multiple-address messages with only a single originating transmission, and the various guards and alarms which are provided to protect against loss of messages in case of trouble (*pages 408–13*).

Magnetic Alloy with Rectangular Hysteresis Loop. The production of a material in which there is an almost complete flux reversal at a field strength almost equal to the coercive force is accomplished in many ways. A study of the method of obtaining this characteristic by means of heat treatments in a magnetic field is given this month (*pages 420–21*).

Lead-Alloy Power Cable Sheath. Recently developed arsenical-lead alloys for sheathing of underground cable have been found in laboratory tests to have better properties in many respects than does commercially pure lead sheath. Beside being able to withstand bending, internal pressures, and tensile strength, the new material stands up better under the handling involved in installing the cable (*pages 415–20*).

Nuclear and Electronic Magnetic Resonance. Dr. K. K. Darrow of Bell Telephone Laboratories, Inc., presents a discourse on magnetic resonance in matter. Discovery of the phenomenon, which occurred in 1945, has been classed as being as important as Bohr's atom model, Schroedinger's wave mechanics, and the discovery of fission (*pages 401–04*).

Electric Railway System. A method of calculating the losses in a d-c supply system for an electric railway has been developed. It was correlated with a measured value of losses and the data were extended to determine the relative merits of proposed feeder changes and rectifier installations on the Providence, R.I., system. It is believed that this is the first published study that has made use of available probability methods for calculating losses, voltage drop, flicker, and capacity requirements for this type of system (*pages 425–31*).

Mechanical Differential Analyzers. In order that engineers may know more about the capabilities and limitations of one type of computer, an analysis of mechanical differential analyzers and their application to electrical engineering problems is presented this month. Topics discussed are magnetic amplifiers, pulse transformers, and particle trajectories (*pages 432–35*).

Power Interruption Testing of Lightning Arresters. In evaluating tests of lightning arresters care must be taken to record voltages and currents very accurately. Measuring instrument characteristics and locations both affect results, and these effects must be taken into account (*pages 443–47*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General
Nov '50, p 44A	Middle Eastern District Fall General
Mar '51, p 35A	Winter General

Resharpening the Recording Styli. A method for resharpening a recording stylus by the use of a sodium hydroxide solvent has led to a study of the burnishing facets of the stylus. The polishing action of the burnishing facet results in the groove wall being smooth and free of noise (*pages 447–50*).

An Electromechanical Transducer. At present, transmission techniques have achieved levels of precision not attainable by the common proportional output transducer. A null-balance transducer which can overcome this deficiency is described this month (*pages 437–40*).

Engineering Must Have Prestige. If public appreciation of the engineering profession is to be stimulated, every engineer must publicize his work and the work of his professional colleagues (*page 407*).

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

CTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. ered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of ruary 28, 1925. May 1951, Vol. 70, No. 5. Number of copies of this issue 54,400

THIS

IS A

PORCELAIN

WATER

COIL

It is used for carrying cooling water to water-cooled vacuum tubes in radio transmission and other heavy-current electronics circuits.

You are not likely to buy such a water coil. Indeed, you may never see one. Yet if you buy or use electrical equipment which incorporates electrical porcelain, you should be interested in the skills of a porcelain-maker who can produce pieces of such critical difficulty as this.

The story goes back to 1929, when radio engineers asked for a porcelain water coil as an improvement over the rubber hose being used which introduced serious difficulties. We viewed the proposal (as would any producer of electrical porcelain) as highly impractical. Yet by 1932, our engineers had developed a satisfactory method for production of these coil Since then, many thousands have been made, produ tion reaching a high peak for an extremely critic World War II requirement. So far as we are awar nowhere else in the world is this product manufa tured. It requires a uniformity of clay production, quality of clay, and an understanding of clay handli techniques achieved in few plants.

You will note that this is a twin-hole tube; t cooling water passes through the outside channel its way to the tube, absorbs the excess heat, and pass back through the inside channel to the cooling a recirculating pumps. The porcelain is produced extrusion through dies and "wound" on a cylindric form. A single coil, after firing, may be as much 35 ft. long. The coil is glazed inside and out, and du ing firing, the glaze seals the turns together to form single rigid piece.

We have a large measure of pride in the acco plishment of production of these coils. It is an acco plishment made possible by skills, techniques and co trols which are available to you in porcelain of highe quality for your system. In high-voltage insulators. porcelain on other equipment. Look for the nar LAPP on porcelain for your system. It's a guarantee sound mechanical and electrical performance, of lo life, of low upkeep. Lapp Insulator Co., Inc., LeRoy, N.

Lapp

What Can We Do About the Shortage of Engineers?

T. G. LeCLAIR
PRESIDENT AIEE

THE DAYS of Neanderthal man, before recorded istory, there was no need for the profession of engi- eering. Every man killed his own food and fought wn battles. The growth of civilization has brought ncreasing need for more and better engineers to pro- the progress of the world. If we are to have con- d progress, the growth and stature of engineers and ngineering profession must continue.

we have a shortage of engineers? If so, why and are we going to do about it? Two stories appeared *lectrical Engineering* in uary 1951, which point sharply toward the com- hortage of trained engi- . The story by S. C. ister,[1] Dean of Engineer- at Cornell University, the one by the author[2] point out that the large bers of engineers grad- d in 1949 and 1950 were tically all absorbed in in- y, but that the future trend appears to indicate that ad of an annual graduating class of nearly 50,000 , this number may be reduced to something like 15,000 954. Both of these stories furnish food for thought e basic shortage which appears to face the country.

Expanding the facilities of technical institutes, training men on the job for specific semiengineering and engineering work, and shifting engineers engaged in nonengineering activities to jobs in their specialty are the three ways President LeClair suggests for overcoming the shortage of engineers in industry and the armed forces.

ARMED FORCES VERSUS CIVILIAN NEEDS

HE APPARENT shortage is made more serious because many of the young men getting out of college may r have an opportunity to be available to industry. picture, of course, changes from day to day, but as story went to press there were indications that many g men getting out of college would be inducted im- ately into the armed forces without it being deter- d whether they were more necessary to industry or to rmed forces. Furthermore, there is a serious problem w young men getting out of high school can be en- aged to carry on and get a technical education. With drafting of 18-year olds, which in effect means high- l graduates, there is a serious problem of what to do t the proper number of young men into colleges. problem becomes difficult because of the fundamental ment that no one group of persons should be exempted draft when others are required to go into military ing. This basic philosophy is in keeping with the rican practice of equal opportunities and equal re- ments for all people. Nevertheless, something must ne for the benefit of the country to get the right kind of men to go into technical training in order that the country can continue to expand and keep its place in competition with other nations who are maintaining a continuous flow of technically trained young men.

MEETING THE SHORTAGE

WITHOUT ATTEMPTING to solve the basic conflict between the needs of the military and of direct employment in industry, let us look at some of the fundamental things which can be done to overcome the shortage of engineers in both fields. The following approaches to this very important problem are worthy of some consideration.

First, it seems desirable to expand the facilities of technical institutes. These schools can train men, and in many cases women, to do highly specialized work of an engineering nature in far less time than the normal 4-year engineering college course. These trained technicians can replace engineers who are now delegated to specialized work, and in all probability a more satisfactory condition would result all around. As a specific example, an engineer with a master's degree who spends all of his time testing insulating oil is wasting his talents. A technician could do this job just as well, and the talents of the trained engineers could be channeled into more productive work.

A second constructive approach is to train men on the job for specific semiengineering and engineering work. A bright high-school graduate can be trained to do certain specialized tasks of an engineering nature without the necessity of having the broader engineering background. Naturally his usefulness would be limited, but nevertheless he could function satisfactorily in an organization with proper supervision. In fact, he might even do a better job in a specialized task than the engineer if the on-the-job training is properly handled.

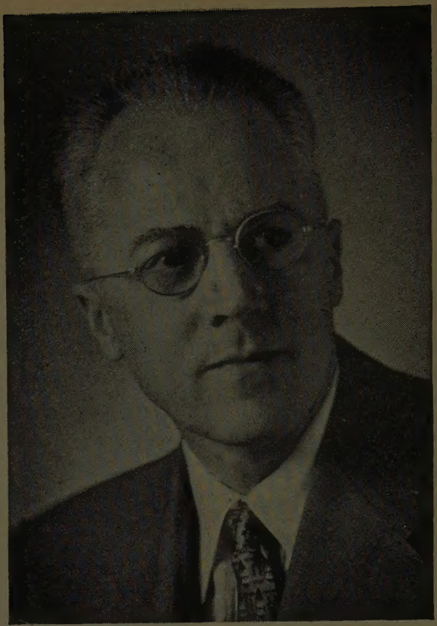
There is a third fertile source for engineers which can be tapped if necessary. That is, each of us, civilian or military, should look in our own organizations to find those persons who are needed in engineering jobs but who are presently engaged in something entirely different. Sometimes, by shifting activities, a man may be put into work for which he is adequately suited but which someone else

---

Abstract of an address presented at the Southern District Meeting, Miami Beach, Fla., April 11–13, 1951.

T. G. **LeClair** is chief electrical engineer, Commonwealth Edison Company, Chicago, Ill.

could also do, and now that the shortage has become acute it would be better to go through that training period to take him out of the nonengineering job and move him into one which will better use that engineering talent. This might be particularly true of some young men who may have taken a job not quite to their liking when there was a rumor that there were more engineers available than jobs. Two or three instances have been brought to my attention where in the military good engineers were available doing nonengineering jobs at the same time that the military were looking for engineers on the outside. I am reminded of an incident of an engineering graduate who did not find a job immediately after graduating from school. In order to make a living, he went back to his father's farm and assumed the duties of a farmer. Naturally he was isolated from engineering societies and contacts with others in the engineering field. As a result, after three years on the farm he was completely unaware of the need for engineers and had no idea as to where to find a job which could use his specialized training.


T. G. LeClair

After we have tapped all the present sources to obtain engineers for the coming increased needs, what can we do to maintain a continuing supply? This is a very difficult problem in connection with the needs of the armed forces, and in connection with the reasonable requirements for universal military service. Both civilians and the military need competent men and they will continue to need competent men in the future. It is necessary to maintain a reasonably continuous flow of technically trained personnel through the normal training channels. It is not too important whether such schooling is obtained under the tutelage of the military or civilian. There may be some difference in the type and speed of training if a man is to be trained while in the armed forces or if he is to be trained as an individual free of any military restrictions; nevertheless, the end goal is just the same.

If we are to have universal military service, and this seemed to be the case at the time this story was going to press, every young high-school graduate must expect to put on a uniform, and he certainly must expect to be subject to rigid military discipline. Can we not work out some scheme under the universal military service whereby in addition to training some men for the various branches of the service we also give to some others a fundamental schooling in engineering? This may be combined with the proper degree of military drill, with barracks life, and all of the other disciplinary needs which are a necessary part of universal service. Through the Reserve Officers Training Corps or through any other suitable means, we should be able to permit a young man to devote a substantial part of his time to his continued education, provided that he meets
acceptable scholarship standa
If and when the need for milit
service ends, these young men n
continue their schooling as ci
ians if they wish.

ENGINEERING MANPOWER COMMISSION

TO ASSIST IN solving the short
problem, the Engineer
Manpower Commission was forr
as a subsidiary of the Engin
Joint Council. The newly elec
Chairman of this Commission
Mr. Carey H. Brown, Eastr
Kodak Company, who has ser
on the Commission since its
ation, and the other members of
Commission are all very promir
men in industry and in educat
The Commission has been ca
into consultation by the Arr
Services Committee of the Sen
by the Selective Services, and by the Department of
fense. The Commission also has prepared material to
given to all high-school principals and many of the hi
school instructors to use in advising their students on
value of an engineering education. This is only the
ginning of their assignment, and it is expected that t
will continue to provide valuable leadership in fac
not only the question of the shortage of men but the me
by which the needs of industry and the needs of the arr
services can be co-ordinated to the better advantage of
whole country.

CONCLUSION

WHATEVER METHODS we may use to meet the pre
problem, it is important that no matter who we
we should not dissipate our time and our talents.
one commodity which is never recoverable is time. If
time of a constructively minded engineer who might
carrying out productive work is permitted to be idle ir
unnecessary post, there has been an irrecoverable loss.
burden of work is increasing and we must use our t
more efficiently. If we are to maintain our present w
leadership not only in civilian pursuits but also in
military activities, we must have sufficient enginee
man power.

All of us as engineers and as citizens should give thou
to the means of making engineers more plentiful and n
useful. It may appear to be a broad problem, but e
of us can be of assistance by seeing, in the way that e
neers are used in our own daily work, that the shortag
solved and that engineers are made available in the fu
for more and better jobs and for broader pursuits.

REFERENCES

1. The Critical Shortage of Engineers, **S. C. Hollister.** *Electrical Engineering*, volu
February 1951, pages 97–99.

2. Continuing Technical Leadership, **T. G. LeClair.** *Electrical Engineering*, volu
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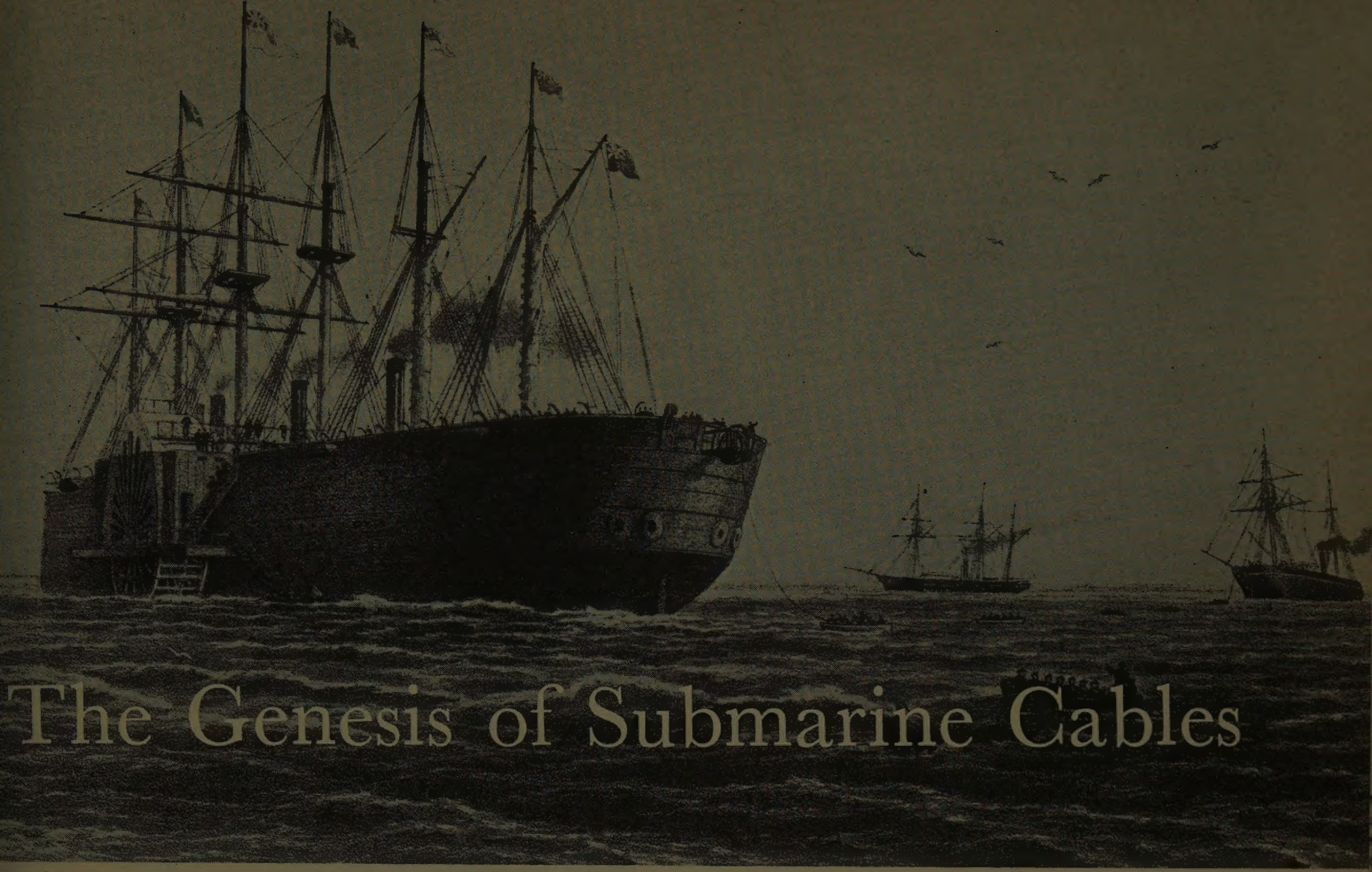

The Genesis of Submarine Cables

g by R. Dudley

From The Atlantic Telegraph by W. H. Russell

LLOYD ESPENSCHIED

FELLOW AIEE

It was a century ago that the first submarine cable was laid between Dover and Calais. To mark this centenary the author reviews some of the events leading up to this achievement which made possible further advances in the communications field, such as laying of the transatlantic cable by the *Great Eastern* escorted by four ships, as shown in the picture above.

REAT NEW developments are made possible in the first place through cal discovery and are ed to reality through hu- enterprise. These crea- orces in man are ever with d stand ready to operate . A recalling of their arance and interplay in irth of the submarine cable, now a century ago, is opriate upon this centenary. It is not only interest- history but affords a perspective that is significant and perhaps suggestive of the future.

r modern electrical age may be said to have begun centuries ago, in the 1740's. It was then that first generated powerful electrical effects, sufficiently "shock" himself into a wholesome respect for the rious force and an intense interest in its possibilities. picturesque period little known to us today, electrical imentation became a great indoor sport of the courts earned societies of Europe, and news of it appeared magazines, constituting a wave of interest similar to rn radio and electronics.

e of the experimenters was a professor of Greek and Latin of Leipzig, Germany, Johann Heinrich Winkler. He wrote three books, the third upon the discovery of the Leyden jar, dated 1746. Then, probably in 1750, he drafted a comprehensive unifying outline of electrical knowledge, saying, in a section on possible applications: "By means of electricity an effect can be produced, such as the firing of a gun or the giving of a signal, at any given time, at a distance as great as one can ask for on earth."[1]

This is the earliest reference to electric transmission the writer has found in the literature. Note the idea of immediacy, the spanning of distances as great as the earth affords, anticipating, as it were, the submarine cable.

Many must have been the ensuing attempts at realizing this dream; the more outstanding we know from the literature. All were doomed to disappointment. The kind of electricity then available was of an impractically high tension; there just was not the right "impedance fit" for practical use.

DAWN

THE DAWN of the electrical age lasted about a century. Daylight emerged with the discovery of a new form of electricity, that of the galvanic cell and electromagnetic

---

t of conference paper presented at the AIEE Winter General Meeting, New . Y., January 22–26, 1951.

spenschied is with the Bell Telephone Laboratories, Inc., New York, N. Y.

mechanical actuation. This more manageable form of electrical technique assumed practical form in the 1830's, accompanied by rapid invention and the appearance of the electromagnetic telegraph in the forms of: Gauss and Weber with their magneto-induced pulse transmitter and sensitive mirror-galvanometer receiver; Stenheil with his use of ground-return; Wheatstone and Cooke with their dancing needles; Morse with his simple and practical recorder that turned into a sounder.[2]

Invention arises from an intermodulation of technical knowledge and human incentive, a feeling of worthwhileness, a circumstance of appropriateness. By the time technical advances made feasible the electric telegraph, starting in the 1830's, interest in telegraphy had risen apace on the Continent, in the form of the optical relay system that had been known in one form or another since the ancients and had received new development through the invention of the telescope.[3] Under the military urge of the French Revolution and the Napoleonic Wars, the Claude Chappe system of semaphore relay had received a great development in France.[4] Morse tells us that by the 1840's such relay chains extended from Paris to the frontiers of France, totalling some 1,400 miles. In fact, what gave Morse the incentive to advance his form of electromagnetic telegraph was the proposal on the part of the United States Government to establish a visual telegraph chain along the eastern seaboard of North America.[5] What made the electric telegraph a success as of the 1840's was this conjunction of the revived optical telegraph, which left much to be desired, with the promising new electromagnetic technique. A further fortunate conjunction at the time was with the building of railroads which needed telegraphy, and in turn could provide rights-of-way.

The optical telegraph stations of Europe had been erected on promontories and towers where they were removed and protected from the populace. Probably it was this situation and the general state of unrest then existing in Europe that occasioned this state of mind concerning the introduction of the electric telegraph: "It was then regarded as altogether out of the question that a telegraph wire easy of access, attached to posts, could be really serviceable, since it was imagined the public would destroy it. Accordingly, wherever on the European continent it was desired to introduce electrical telegraphs, experiments were first made with subterranean conductors. The best known were those of Professor Jacobi in St. Petersburg. He had tried resin, glass-tubes, and Indian rubber as insulators, but had obtained no permanently satisfactory results."[6] We have this from the man who pioneered the introduction of the telegraph in Germany for the Prussian State in the 1840's, Werner Siemens, who founded the famous electrical firm of Siemens and Halske. The first telegraph line in the United States, that of Morse between Baltimore and Washington, likew
was started on an underground basis. But this proved
be so difficult as to quickly lead to the overhead wir
which characterized telegraph development in this count
where the distances were great and the highways w
hardly more than ruts through the forest.

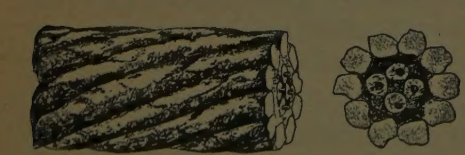
From Submarine Cables by Charles Bright

Figure 1. Piece of channel cable laid between Dover and Calais in 1851

MANNA FROM MALAY

REMARKABLE it is that at this juncture, in the 184
there came to Europe from Malay a much need
insulating material, gutta percha. It might have b
introduced earlier had the Europeans been interested
such a thing, for it seems the material had been in Engla
as early as the middle 1600's.[8] What caused it to attr
attention was the readiness with which it could be mol
upon being heated to the temperature of hot water,
distinct from India rubber which retained its stiffness a
elasticity. William Siemens, then living in London, s
a sample to his brother Werner in Berlin[9] who later wr
of it: "The remarkable properties of this material,
becoming plastic in the heated state, and when coo
being a good insulator of electricity, aroused
attention."[10]

Werner Siemens covered pieces of wire with the hea
material, found they were thoroughly insulated, and t
devised a screw press whereby the plastic could be cohesiv
pressed around the copper wires in a continuous proc
The first introduction to salt water of gutta percha insula
wire occurred in 1847 when Siemens laid a submarine m
in the harbor of Kiel that was to be electrically detona
from the shore. A gutta percha insulated telegraph l
was laid underground from Berlin starting in 1847, and
the following two years extended to Frankfort along a n
railroad.[11]

In England electric telegraph exploitation, by Whe
stone and Cooke, started as early as 1838, applied to
railroads, using both underground and overhead c
struction.[12] Gutta percha had been made into bot
and tubes in 1846; in 1848 Faraday called attention t
as an insulating material;[8,9] and upon the realization of
pressure-extruding process it was put to work for tel
raphy to become the foundation of the submarine ca

COASTAL SUBMARINE CABLES

THE GUTTA PERCHA insulated line was to get its
baptism as a telegraph cable in 1850, in a bold
tempt, led by Joseph Brett, to span the English Chan
between Dover and Calais. It was a single wire, gu
percha enveloped, with no outer protection. The ca
failed almost immediately; but the ability to produce
lay it had been demonstrated and the need of better
chanical protection had been proved.

The project was renewed the following year, this t
with a cable of four conductors individually insulated
layed up together. Aid had now been sought of anot
industry, that of wire-rope making for coal mines.
group of insulated conductors was embedded in the ce
of a wire rope. This, the first armored cable, was succ
fully laid and marked the beginning of the subma
telegraph, the Dover-Calais Cable of 1851, the centen

hich is being commemorated this year[13] (see Figure 1). is at the onset of a new development that the imagina- runs highest, before minds get set in a new groove. book by Edward Highton on "The Electric Telegraph," lished the following year, 1852, appear some curious es of these first attempts at extending electrical paths ugh the sea. The author opines that upon our learning electric fish project their bolts into the sea, there may 'discovered a means of constructing submarine tele- hs without any insulation of the wires: and who shall whether such a discovery would not satisfactorily solve problem of communicating instantly between Great ain and America."[14] The same book, under a section ioned "Telegraphing Without Insulation," recalls : "Various experiments have been tried in England, erica, and India, with a view to ascertaining whether as possible to send telegraphic communications with ed wires, or even without any wires at all."[15]

o sooner had a new insulating material become avail- than inventors were trying to eliminate it, and even conductor itself. Truly, inventors are ungrateful. reshadowing of radio, or what?

the ensuing years additional shallow-water cables e undertaken along the European shores, with the usual rnation of failure and success. Experience accumu- d, improvements mounted in the manufacture and test- of the cables, in the handling and laying of them, erience that extended to deep-water cables in the diterranean; all the pain and joy of the birth of a new

ATLANTIC CABLES

y 1856 the European telegraph network had grown westward to Ireland, the North American network ward to Newfoundland. The challenge of bridging great barrier of the North Atlantic was soon accepted daring spirits on both sides of the Atlantic, notably us W. Field and John W. Brett, who joined in common rprise.[16]

he first undertaking was in 1856–57. The cable was ollow a route sounded between Valentia, Ireland, and ity Bay, Newfoundland. The manufacture and ing of the 2,000-odd miles of cable, the paying of it into the depths of the Atlantic from heaving ships, the cting of the received signals rendered microscopic that great distance—all constituted the greatest blem yet undertaken in the embryo electrical age. laying of the cable started from the Valentia end. en deep water was encountered, the paying-out ma- ery proved inadequate; the preparations had been rushed. The operation had to be suspended pending rovements and the acquiring of more cable.

Jndaunted, the expedition started out anew the follow- year, employing the same vessels: *H.M.S. Agamemnon* Figure 2) and the United States steam frigate *Niagara*. s time they started paying out cable in opposite direc- s from a splice in mid-Atlantic. There were troubles, finally the laying was completed. Congratulatory sages flashed back and forth, heralded on both sides of Atlantic; jubilation reigned;[17] literature was full of the occasion. A quaint little book[18] appeared in 1858 that set forth in verse the entire history of electrical discovery from the time of the Greeks, in terms of the experiences of the Sprite "Electron." In it the author had anticipated:

Drawing by R. Dudley
From The Atlantic Telegraph by W. H. Russell

Figure 2. ***H. M. S. Agamemnon* laying the Atlantic telegraph cable in 1858. A whale crosses the line**

> "Soon shall Electron glide beneath the Sea,
> Betwixt two worlds, their messenger to be!"

The poem bears the prophetic title *Electron*, and the name of the imaginative poet-historian: William C. Richard.

But the songs of praise were premature; within a few weeks Jinx Electron glided off the wire into the sea, as the insulation failed. The chagrin of the financial backers can be imagined. For them it was an "all or nothing" adventure, and they proved to draw nothing as the cable of 1858 lay silenced and abandoned. About the same time there had been undertaken, in sections, a cable from Suez eastward to India, and it, too, ended disastrously.

The British government had assumed financial responsibility in these projects and now became aroused. Through the Board of Trade there was initiated a joint government-industry committee, charged with going into the subject thoroughly, with the aid of such eminent scientists and engineers as Wheatstone, William Thomson, Charles Bright, the two Varleys, and Latimer Clark.[19]* The finding was constructive—assurance was given that cables could be successfully laid and operated, and more rigorous procedures, including testing, were specified. In fact, this co-operative study may be said to have initiated the formulation of our electrical standards and units.[20]

Further experience was had in the 1860's, with cable projects along the road to India (see Figure 3). Meanwhile, in America, the Civil War raged. Competitive American enterprise entered upon an alternative route to Europe, the overland route through Alaska and Siberia, a

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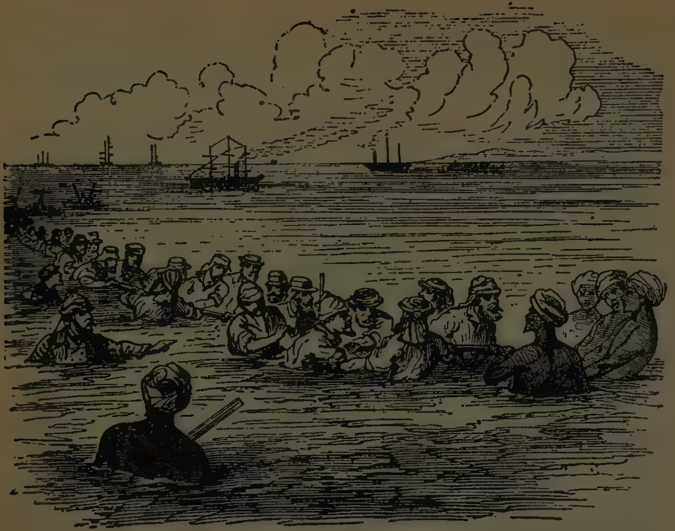
* It was Latimer Clark who made the remarkable collection of early electrical books which were purchased by S. K. Wheeler of Crocker-Wheeler and given to the AIEE, presently in the Engineering Societies Library. Its contents are listed and explained in a 2-volume Catalogue of the Wheeler Gift, published by the AIEE, 1909.



From The Electric Telegraph by D. Lardner

Figure 3. Landing the Indo-European Telegraph Cable in the mud at Fao, Persian Gulf

project that was actually started but dropped when the Atlantic cable materialized.[21]

Some years lapsed before the courageous pioneers of the Atlantic Telegraph again rose to the challenge, but in 1865 the project was renewed. The cable laying was done this time by the famous *Great Eastern*. She started paying out cable from Valentia westward toward Trinity Bay (see Figures 4, 5). Difficulties were encountered, but the laying went on, up to two-thirds of the way. Then, in the course of picking up injured portions to make repair, the cable was lost, including a great length of grappling rope. The expedition returned—"shattered in hopes as well as in ropes," as Bright tells us.[22]

The following year the attack was renewed. Such persistance in the face of adversity is worthy of a rugged age and a great objective. Victory at last; two-fold victory because the cable of the previous year was picked up and completed also (see Figure 6). So 1866 goes down in the book of cable genesis as witnessing "the great feat of the century" as Morse called it: the joining of Europe and America.

THE UNDERLYING ELECTRICAL PROBLEM

Behind the pioneering projects outlined here and continuing down to today and into the future is the fundamental problem of electric transmission; that of the toll taken in energy and time delay, in projecting electromagnetic waves to great distances. The progress made in meeting this basic problem now is traced briefly.

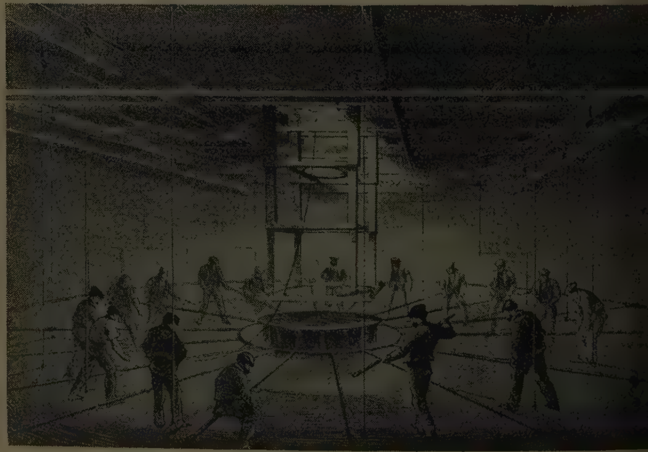
The fact that a well-insulated cable, open at the far end, would "soak up," and in turn discharge, an electric current, was observed by Siemens in 1847 in the course of testing his original gutta percha insulated underground lines.[23] The effect of this electrostatic induction in slowing up the signalling had been not too severe in the shorter coastal cables, but had raised grave doubts as to working across the Atlantic. Experiments on underground wires in England on lengths upward of 2,000 miles showed that dots could be transmitted at the rate of about four per second.[24] This was thought to answer the initial cor
mercial requirement, and the undertaking of the Atlan
cable had followed. The trailing effect of the signals w
curtailed by sending dots of opposite polarity alternatel
this practice characterizes ocean cable telegraphy.

Following the failure of the first Atlantic cable of 185
additional experience obtained in the manufacture a
testing of cables in England rapidly fortified the insulati
situation. The proportioning of the cable as to diameter
conductor and of insulation in respect to speed of signalli
came under study and took on the semblance of enginee
ing. Through the contributions of the two Varleys and
William Thomson, it became recognized that the resistan
as well as the capacity of the cable affected transmissio
Since the speed of signalling was proportional, inversel
to each of these constants, and since each increases with t
length of the cable, the speed of signalling was recogniz
to diminish as the square of the distance. This adver
law called for careful scrutiny of the cable dimensions a
constants, and the next attempt at the transatlantic pro
lem was to have the benefit of this engineering knowled
Thus was born the famous *KR* Law (capacity times r
sistance) as a measure, inversely, of the speed of signalling
the forerunner of the more complete propagation la
(which includes series inductance and shunt leakage) th
was to be appreciated in the age of telephony.

APPARATUS AND EVOLUTION

There were two principal features in the apparat
employed for working these early cables: special ke
for sending the plus and minus current pulses; and t
use of the reflecting galvanometer, originally employed
the Gauss and Weber telegraph, improved by Helmhol
and developed in highly sensitive form by William Thor
son, later Lord Kelvin.[26,27] The spark recorder follow
and then the syphon recorder. Ocean cable recepti
from the beginning was a matter of eye reading of t
sinuous feeble wave. Through the century we have h
the submarine cable. So great have been the advanc
that we cannot do justice to them all, but we might reca

1. Interest in, and an exploring of, earth currents



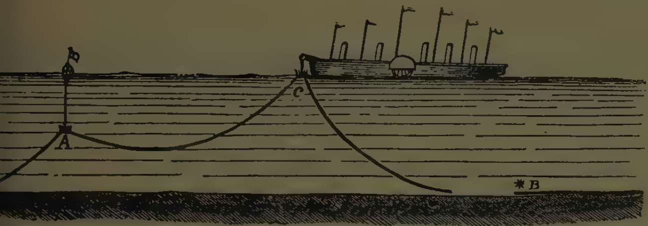
Drawing by R. Dudley

From The Atlantic Telegraph by W. H. Ru

Figure 4. Interior of one of the tanks on board the *Great Easte* Cable is being passed above to the deck

wing by R. Dudley From The Atlantic Telegraph by W. H. Russell

ure 5. **Paying-out machinery on deck of the *Great Eastern***



From The Electric Telegraph by D. Lardner

ure 6. **Diagram showing final arrangement for picking up le of 1865. (A) Point where cable was buoyed to the east by *Great Eastern*. (B) Point where cable was broken by the *Medway*. (C) Bight of cable brought to surface**

2. Reduction of earth-current effects, and a favoring the higher frequency components of the signal wave, the use at the terminals of capacitors or transformers— ort of d-c carrier suppression and equalizing action.

3. Improving transmission by increasing the series luctance, that is, loading.

4. The long series of attempts at amplifying and re- ating, ending in the electron amplifier.

Curiously, an enterprising American in 1865 advanced idea of submerged repeaters, sealed in bombshell-like ntainers inserted in the cable.[28] But a long-life non- justable repeater was missing.

"RETRO-PROSPECT"

HE ESTABLISHMENT of the Atlantic Telegraph concluded the pioneering stage of the submarine cable. Yet in a oader sense the pioneering continues down to the pres- time, as is seen in the radical departure described in ompanion paper,[29] of including electron tube repeaters hin the armor of the cable of the new Key West-Havana ephone cable system.

The underlying trend of advance has been one of widen- the transmission band and increasing the rate of nalling, thanks to loading in the first place and, more ently, to the vacuum-tube amplifier. Long before the plifier, in the 1890's, Tesla dreamed in vain of a trans- ntic telephone cable.[30,31] Today we know the Atlantic ephone cable can be realized.[32] It is a matter of economics, especially in comparison with radio. Meanwhile the art progresses; multichannel carrier working expands. Even more remains to be accomplished, for the sense of sight demands to be transmitted across the seas in this age of television, and the bottom of the sea is well removed from the earth's surface turmoil.

It took a century to realize the electric telegraph and submarine cable. We have had a century of use and advance. What has the third century in store for us, now that the magic Jinx Electron is fully loosed embraced with electromagnetic waves? Surely the Book of Genesis still lies open. Future history may well record that the full Genesis of electric communications, under as well as over the sea, took three centuries.

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Aircraft Navigation Instruments

W. L. WEBB
ASSOCIATE AIEE

Many of the instruments which are used by aircraft navigators are described here. These instruments are designed to be direct reading, unambiguous, and accurate; they must be compact and lightweight, as well as easily seen.

INFORMATION as to the heading and position of an aircraft must be available to the pilot in a usable, continuous, and accurate form. Instrumentation used for navigation by the pilot will be discussed, but no reference will be made to flight, engine, or altitude instruments. Further, no mention will be made of instrumentation used by the navigator on long transoceanic flights.

The instruments required by a pilot to navigate a modern aircraft on domestic federal airways must be direct reading, unambiguous, and accurate. The information available on federal airways now or in the near future requires all or part of the following instruments in the cockpit:

1. Magnetic Heading Indicator.
2. Automatic Direction Finder Indicator.
3. Radio Magnetic Indicator.
4. Omnirange Bearing Selector.
5. Cross Pointer Instrument—includes Deviation Indicator for localizers and omnirange bearings as well as glide path indicator.
6. Omnirange Bearing Indicator.
7. Distance Indicator.
8. Omnimagnetic Instrument—combination of relative magnetic headings, cross pointer, and omnibearing Selector into one instrument.

This article will be confined to a description of the design and operation of these instruments. Reference will be made to the information fed to these instruments only when necessary to explain their operation. All bearings referred to are clockwise from magnetic north.

1. Magnetic Heading Indicator. Although the geographic position of an aircraft may be known by other references, it cannot be flown without re erence by the pilot to i heading. Position devic alone do not indicate the d rection in which the aircra is flying; hence, a headin indicator is required. Th commonly accepted heading indicator is magnetic an always indicates the heading in degrees, clockwise fro magnetic north.

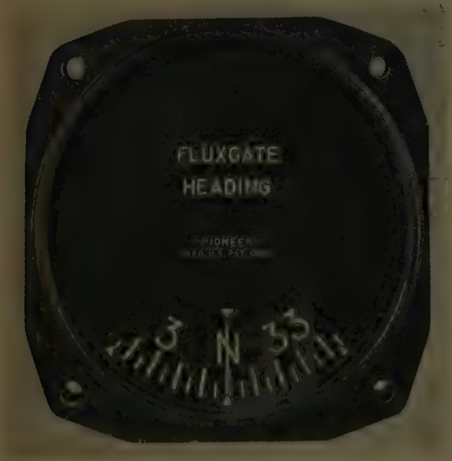

Figure 1. Flux gate remote heading indicator

Modern aircraft carry a gyro-stabilized magnetic headin device, one type of which is the flux gate compass. It has n turning error, is corrected for aircraft deviation, and th heading is displayed on a remote indicator, as shown i Figure 1. The flux gate master indicator also will sho heading and combines a number of functions other tha indication. An operational schematic explaining th operation of the flux gate system is shown in Figure 2.

2. Automatic Direction Finder Indicator. The standar automatic direction finder (ADF) indicator, Figure usually has two pointers and is arranged so that the arro head of each pointer points toward the radio station selecte for that pointer. The single scale is calibrated from 0 360 degrees and can be manually set to the magnetic hea ing of the aircraft by the pilot.

It contains two repeater synchros, each of which rotat in synchronism with a loop antenna. Its construction shown in Figure 4, consisting of a hermetically sealed cas rotatable scale, synchros with a pointer on the shaft of eac and a plug for external connections. The shafts of the tw synchros are concentric, one being hollow to accommoda the shaft of the rear synchros.

Basically, this indicator furnishes the following inform tion to the pilot, as shown in Figure 5.

1. Relation of station to aircraft, giving a quick visua ization of the direction of the station relative to the aircra heading, since the arrow head of the pointer graphical points to the radio station and relative bearing.
2. Magnetic bearings to or from the aircraft to the st tion as read at head or tail of the pointer; 250 and 70 d grees respectively, as shown in example in Figure 5.

The advantage of the ADF has always been its simplici of use in visually indicating the direction of the radio stati without mental computation. It is very helpful for orient tion on low-frequency radio ranges, establishing a headi on a range beam with cross wind, homing, approach pr cedures to an airport, and radio fixes. It is standa equipment on all military and multiengine civil aircra

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Full text of a district paper presented at the AIEE Middle Eastern District Meet Baltimore, Md., October 3–5, 1950.

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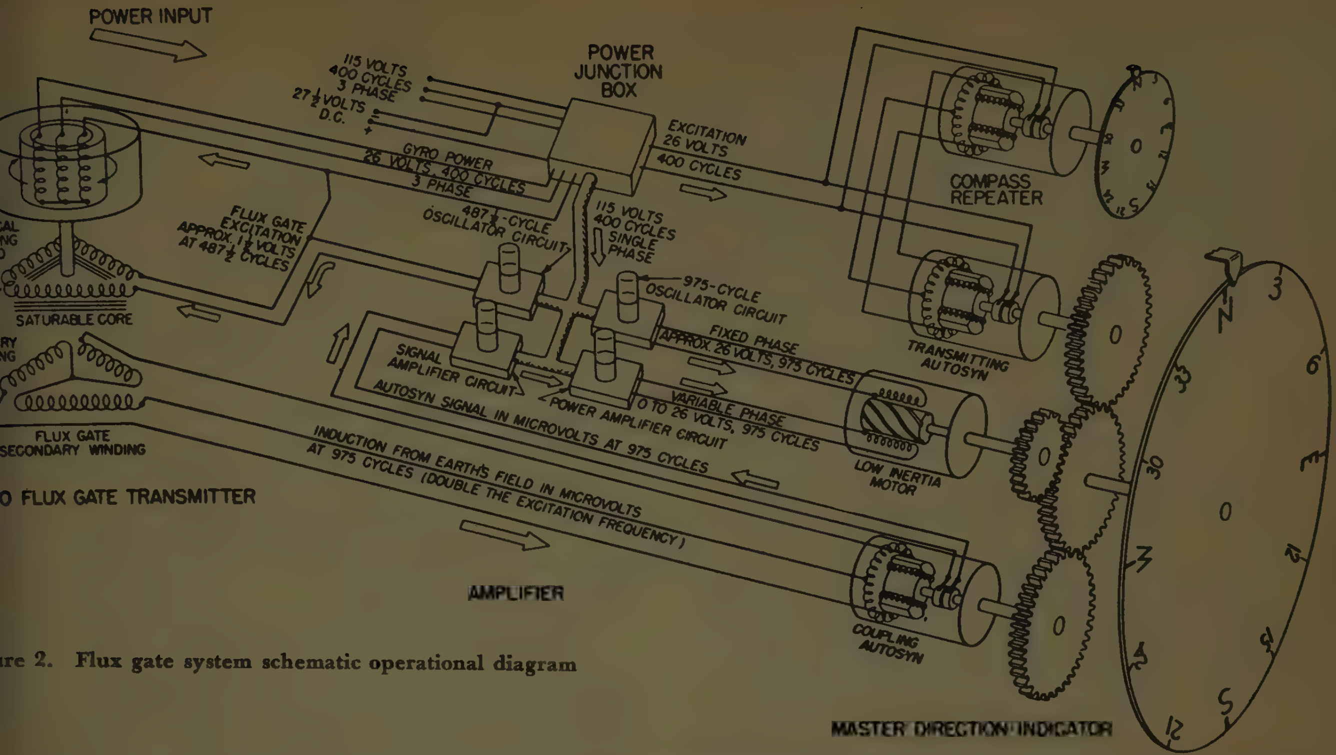

POWER INPUT
115 VOLTS 400 CYCLES 3 PHASE
27½ VOLTS D.C.
POWER JUNCTION BOX
GYRO POWER 26 VOLTS, 400 CYCLES 3 PHASE
EXCITATION 26 VOLTS 400 CYCLES
COMPASS REPEATER
FLUX GATE EXCITATION APPROX. 1½ VOLTS AT 487½ CYCLES
487½-CYCLE OSCILLATOR CIRCUIT
115 VOLTS 400 CYCLES SINGLE PHASE
975-CYCLE OSCILLATOR CIRCUIT
SATURABLE CORE
FIXED PHASE APPROX 26 VOLTS, 975 CYCLES
TRANSMITTING AUTOSYN
SIGNAL AMPLIFIER CIRCUIT
VARIABLE PHASE 0 TO 26 VOLTS, 975 CYCLES
POWER AMPLIFIER CIRCUIT
AUTOSYN SIGNAL IN MICROVOLTS AT 975 CYCLES
LOW INERTIA MOTOR
FLUX GATE SECONDARY WINDING
INDUCTION FROM EARTH'S FIELD IN MICROVOLTS AT 975 CYCLES (DOUBLE THE EXCITATION FREQUENCY)
O FLUX GATE TRANSMITTER
AMPLIFIER
COUPLING AUTOSYN
MASTER DIRECTION INDICATOR

re 2. **Flux gate system schematic operational diagram**

. *Radio Magnetic Indicator.* The radio magnetic indi-
r (RMI) is similar to the ADF indicator, except that
scale is automatically and continuously rotated to the
raft heading by remote information from the flux gate
gnetic compass. The pointers may be fed information
n the ADF as described in the preceding section and
nt to the station. However, the instrument is more
atile as the magnetic bearing to or from the radio station
vailable continuously without the necessity for the pilot
ually setting the scale to the aircraft heading. The
t view, shown in Figure 6, is identical to the ADF indi-
r in Figure 4, except the knob is removed as it is not
ded.

n addition to ADF indication, this instrument is used to
vert very-high-frequency omnirange bearings to ADF-
heading sensitive indications by combining heading
n omnirange bearing. This is covered in more detail in
section on omnirange indicators.

he construction of the RMI is rather complex as the
ts of three synchros must be concentric at one point.
lier designs required a servomechanism with a gear
n and motor to obtain sufficient torque to position accu-
ly the scale drive to its weight and shaft friction. How-
, in the latest design, refinement of bearings, low-
ion gears, and higher torque synchros have eliminated
servo, and the two pointers and scale are driven di-
ly by synchros. A precision arrangement of low-torque
low-friction bearings and gears allows the
chros to be offset; otherwise, the instrument
ld become too long and bearings too
e in diameter. An internal view in Fig-
7 shows this arrangement. The unit is
metically sealed and filled with dry nitro-
to protect the bearings' lubrication from
lation and contamination. When it is
embered that only a 2,500-milligram-
imeter torque at 1-degree displace-

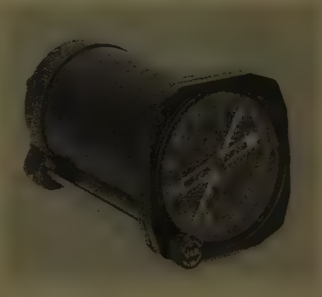


Figure 3 (above). Automatic direction finder indicator MN-58

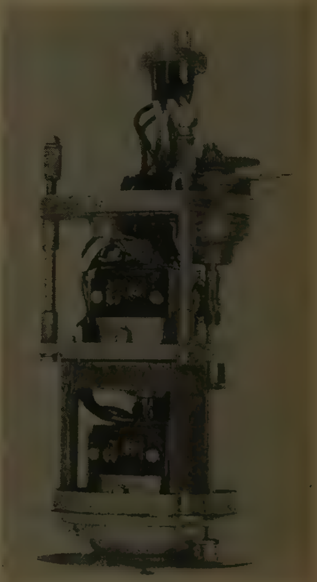
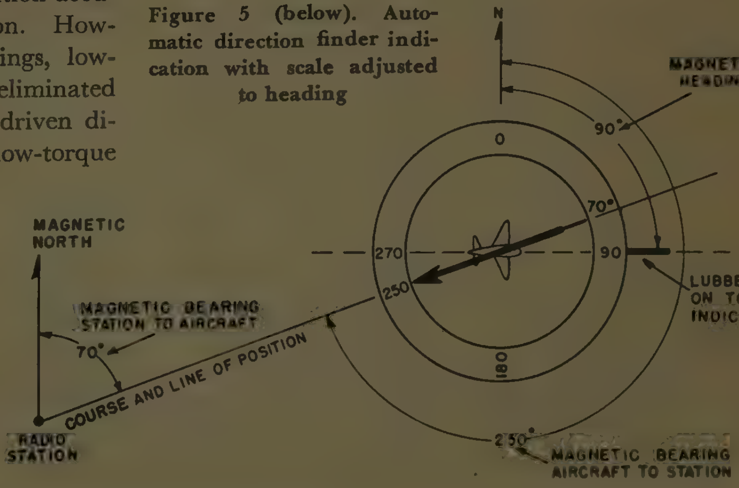
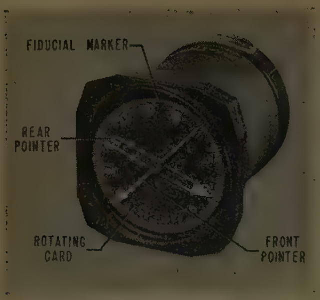


Figure 4 (right). Internal view of the automatic direction finder indicator

Figure 5 (below). Automatic direction finder indication with scale adjusted to heading


N
MAGNETIC HEADING
90°
0
70°
270
90
250
LUBBER LINE ON TOP OF INDICATOR
180
MAGNETIC NORTH
MAGNETIC BEARING STATION TO AIRCRAFT
70°
COURSE AND LINE OF POSITION
RADIO STATION
250°
MAGNETIC BEARING AIRCRAFT TO STATION



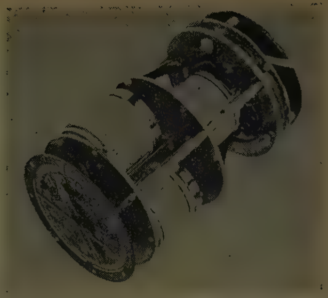


Figure 6 (left). Radio magnetic indicator

Figure 7 (right). Internal view of the radio magnetic indicator

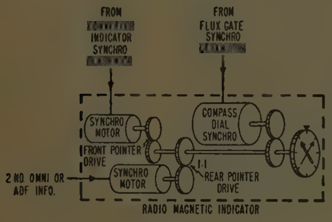


Figure 8. Block diagram of the radio magnetic indicator

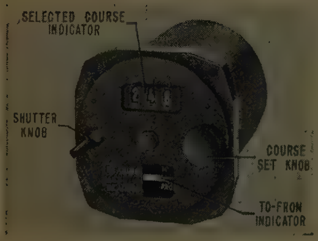


Figure 9. Omnibearing selector MN-82

ment is available from these miniature synchros, which are only 1 inch in diameter and $1^{1}/_{8}$ inches long, the precision with which the bearings and gears must be made and protected can be realized. A block diagram showing the operation of the RMI is illustrated in Figure 8.

Refinement of design and hermetic sealing has made these instruments very reliable in spite of their delicacy, and they seldom fail in rugged aircraft service.

4. *Omnirange Bearing Selector.* The very-high-frequency omnidirectional radio range station provides output from an aircraft receiver which consists of a 30-cycle voltage of fixed phase and a second 30-cycle voltage of variable phase. The phase difference between these two receiver outputs is dependent upon the position of the aircraft in azimuth, relative to the station. If the aircraft is on magnetic north from the station, the two 30-cycle voltages are in phase; if the aircraft is at 90-degree azimuth, the 30-cycle voltages are 90 degrees out of phase; at 180-degree azimuth they are 180 degrees out of phase, and so forth.

A direct-reading phase meter, properly connected to the receiver output, would directly indicate, in degrees, the magnetic bearing of the position of the aircraft relative to the station.

It is more convenient in operation and flying to use a phase-setting dial in connection with a right-left indicator, so that a given bearing can be set manually on the dial. The aircraft then is flown to hold the right-left meter on zero-center, making the track of the aircraft correspond the course set on the dial.

The omnirange bearing selector consists of a tape w degree marking which shows through the window, a kn geared to an electrical resolver, a d-c meter movement eliminate 180-degree ambiguity in bearing, and a mech nism for quickly shifting the selected bearing by 180 grees. The phase shifting is done magnetically in a solver having a 2-phase stator and a single-phase rotor. the rotor is turned, the phase angle of the 30-cycle outp voltage of the rotor winding changes in the same amount the rotor is turned. A tape scale geared to the rotor sh indicates the angle to which the rotor is set. The scale calibrated to read the magnetic bearing from the aircraft the omnirange station, or its reciprocal.

Details on exact arrangements for phase shifting, ph splitting, and phase comparison will not be given, as thi covered in other publications and this paper is concern only with instrumentation.

To reduce cost the bearing selector usually is not h metically sealed, as no low-torque bearings are requir The ambiguity meter is a d-c meter movement so arrang to read *TO* or *FROM*, thus indicating whether the beari shown in the window is the bearing to or from the stati

A view of the instrument is shown in Figure 9. A blo diagram of the bearing selector is shown in Figure 10.

The bearing selector is used in association with the cr pointer indicator.

5. *Cross Pointer Indicator ID-48.* This instrument is standard aircraft instrument panel case containing four microammeter movements. One movement operates vertical pointer for use with the omnibearing selector flying omnirange courses and instrument landing locali courses. A second movement operates a horizontal poin for maintaining the aircraft on a glide path during an strument approach to a runway on instrument landi system. The other two movements operate red flags asso ated with each of the pointers to indicate malfunctioning either system. All movements are on the order of 1

Figure 10. Block diagram of the omnibearing selector MN-82

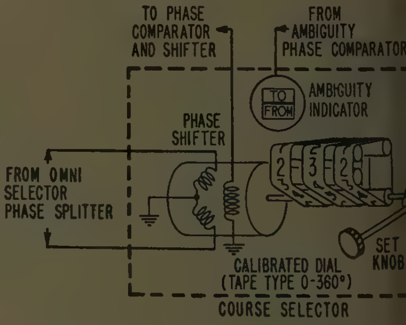
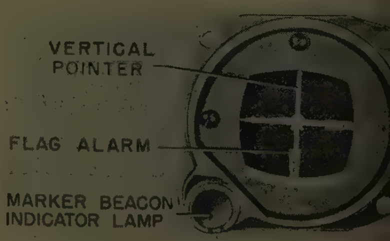

TO PHASE COMPARATOR AND SHIFTER
FROM AMBIGUITY PHASE COMPARATOR
TO
FROM
AMBIGUITY INDICATOR
PHASE SHIFTER
FROM OMNI SELECTOR PHASE SPLITTER
SET KNOB
CALIBRATED DIAL (TAPE TYPE 0-360°)
COURSE SELECTOR

Figure 11. Cross pointer indicator ID-48



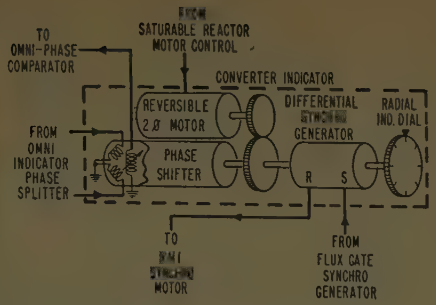


Figure 12 (left). **Omnibearing converter-indicator**

ure 13 (right). **Block diagram of the omnibearing converter-indicator**

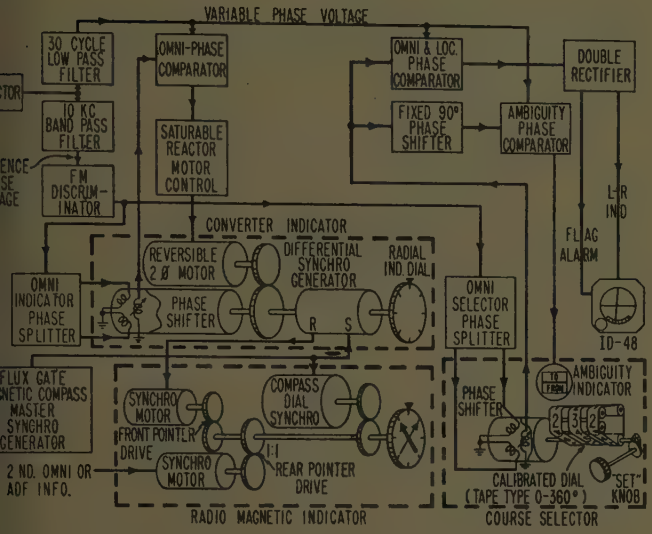


Figure 14. **Block diagram of automatic phase instruments**

croamperes for full scales. The instrument has been de-
ned to withstand rugged aircraft service and is standard
all large aircraft. A view is shown in Figure 11.

Omnibearing Converter Indicator. Although this instru-
nt is seldom used in the cockpit for actual navigation, it is
essential part of the omnirange aircraft equipment to de-
automatic bearings for combination with heading to
erate the RMI. It consists of a phase shifter, gear drive,
ferential synchro, and bearing scale on one shaft. A
w is shown in Figure 12, and it is diagrammatically
wn in Figure 13. The phase shifter operates in the
ne manner as the omnibearing selector phase shifter, ex-
t that the shaft is driven to the actual bearing by a servo
iving its torque from the voltages available when the re-
ver-output 30-cycle voltages are out of phase. The shaft
positioned automatically by a null occurring when the
tages are in phase. An over-all block diagram showing
receiver output, radial converter-indicator, omnibearing
ctor, and RMI is shown in Figure 14. A differential
chro, which will take two inputs and add them alge-
ically, is driven by the omnibearing shaft to add mag-
ic heading algebraically to the omnibearing. A little
ught will show that this will result in relative bearing to
d a pointer on the RMI, thus creating an ADF on a very-
h-frequency omnistation. The advantage of a heading sensitive indication such as this is hard to visualize unless you have attempted to orient yourself in an aircraft by a position sensitive indication only, such as the direct reading obtained from the omnibearing converter-indicator. It tells the navigator he is on a definite line of position in space, but does not tell him how he is heading relative to that line of position. He can fly a circle at that position and the bearing indication does not change, but the RMI does change and always points to the station.

7. *Distance Indicator.* To complete the position information by reference to one geographic point on the ground, a measurement of distance is required. Special pulse interrogator-responder equipment has been developed to give direct reading of distance from the aircraft to an omnirange station or end of runway on one instrument. This system is not in general operation yet, but will be by 1952. The instrument for distance indication is shown in Figure 15. The design is not frozen as yet, but the counter-pointer type has been tentatively selected to prevent confusion with other aircraft instruments, such as an altimeter, and to show the rate of approach to the runway.

The combination of omnirange bearing and distance, known as the *R-θ* system, allows ready application of the offset computer to allow parallel airways of the future to be flown by reference to a single omnirange-distance-measuring-station on the ground.

8. *Omnimagnetic Indicator.* This instrument combines the cross pointer indicator *ID-48* and the omnibearing selector and is shown in Figure 16. A third relative heading needle has been added to assist in flying an omnirange or localizer course. It was developed for two reasons: (1) to conserve valuable instrument panel space, and (2) to add the vital relative heading to the position needle. It is beyond the scope of this article to go into the necessity of adding relative heading to the position pointer, but it is sufficient to state that it is impossible to fly the aircraft without reference to a heading indicator. This instrument makes it unnecessary to look at a second instrument during a diffi-

Figure 15. **Distance-measuring equipment indicator**

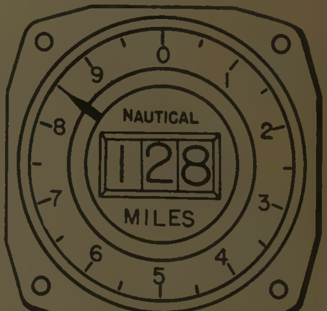
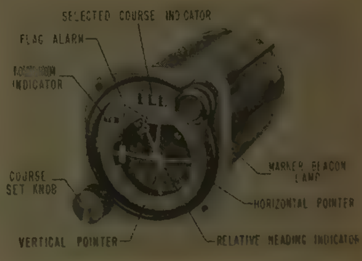


Figure 16. **Omnimagnetic indicator**



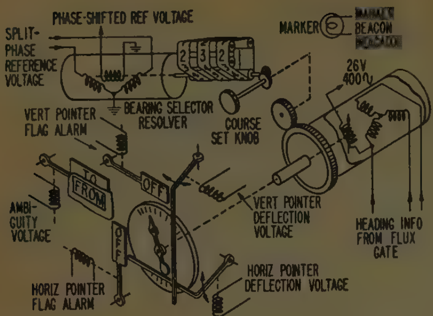

PHASE-SHIFTED REF VOLTAGE
SPLIT-PHASE REFERENCE VOLTAGE
MARKER
BEACON
2
3
2
26V 400∿
BEARING SELECTOR RESOLVER
VERT POINTER FLAG ALARM
COURSE SET KNOB
TO
FROM
OFF
AMBI-GUITY VOLTAGE
VERT POINTER DEFLECTION VOLTAGE
HEADING INFO FROM FLUX GATE
OFF
HORIZ POINTER DEFLECTION VOLTAGE
HORIZ POINTER FLAG ALARM

Figure 17. Block diagram of the omnimagnetic indicator

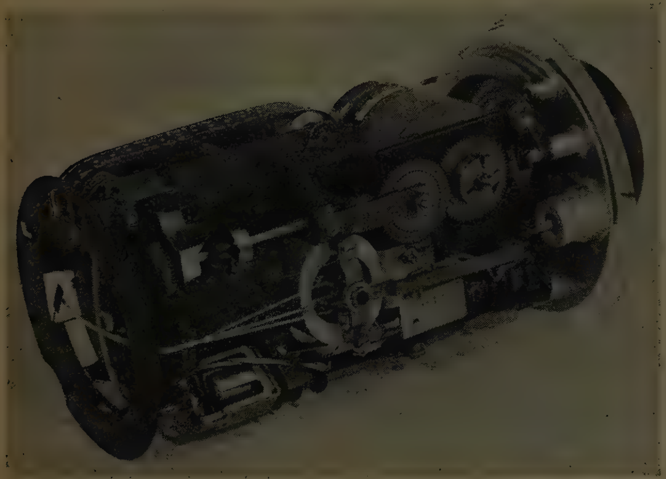


Figure 18. Internal view of the omnimagnetic indicator

cult instrument letdown, and eliminates the necessity for mentally computing different headings as an instrument landing letdown procedure to an airport is executed, as the heading of the aircraft relative to the selected course is always visualized instantly.

The instrument consists of five microammeter movements, a tape calibrated in degrees geared to selector kno and heading synchro stator, and a phase-shifting synchr A block diagram is shown in Figure 17. The selector kno calibrated tape, and phase-shifting synchro operate identic to the omnibearing selector *MN*-82. In addition, th stator of a repeater synchro, deriving its rotor position fro the magnetic heading of the remote flux gate compass, geared to the selector knob. It is so arranged that whe the heading of the aircraft is the same as the course electe and the aircraft is on course, the short relative headin pointer will be vertical and aligned with course deviatio pointer. If the aircraft is turned right, relative headin pointer will point right; and if the aircraft is turned lef pointer will point left—showing the degrees turned.

This instrument represents the utmost in complexit and considerable design ingenuity was required to contai two synchros, five meter movements, gearing, and calibrate tape in one standard $3^1/_2$-inch aircraft instrument case an hermetically seal it, as shown in Figure 18. The five mete movements are vertical course pointer, horizontal glide pat pointer, vertical pointer flag alarm, horizontal pointer fla alarm, and ambiguity indicator. The pointers mov linearly instead of around a pivot to allow better visualization by the pilot of himself at center circle and of the desired paths at location of pointer to allow "fly to needle technique.

It should be noted that all external rotatable knob functions are connected through the hermetic seal of the instruments by a hermeflex joint. This is a bellows with a eccentric motion developed for such applications.

In conclusion, it can be stated that the aircraft navigatio instruments described in this paper do represent the maj complement that are or will be used in all airlines and mo military aircraft to navigate on federal airways. Som other instruments are in limited use or have been propose but it is felt that those described give a composite view those most generally used.

Electronic Machine Developed for Counting Worn-Out Money

A fully automatic electronic machine for counting worn-out money has been developed by the National Bureau of Standards (NBS) for the Department of the Treasury. The currency counter counts 30,000 notes per hour. Twenty-five of these machines will be placed in service soon by the Treasury, replacing the present hand-count system and saving about $250,000 annually.

Although new paper money has been machine-counted for many years, mechanical handling of worn-out notes has been a problem. About eight tons of currency are turned in daily for redemption, and the notes are wrinkled, limp, and difficult to handle. The variable condition of returned money has required tedious counting by hand.

Money returned to the Treasury is in the form of packets of 100 notes cut longitudinally into half-notes. These stapled packets are placed on an inclined trough and pushe into the machine. The stapled end is grasped by met jaws and the packet is wrapped tightly around a spindl spreading the outer edges of the notes against a frictic band. As the spindle rotates the notes clear the frictic band and are separated by a jet of air.

The counting is achieved by using an electronic sen ing device consisting of a beam of light and a phototu system. As the notes unfurl, interrupting the beam of ligh the phototube senses the interruptions of the beam. I pulses from the phototube are fed to a binary count which tallies the individual impulses. The sum of the impulses is used to actuate a sorting vane, automatica rejecting packets if the count is more or less than 10 Except for filling the trough, machines operate unattende

Die-Cast Rotor Studies

L. C. PACKER
MEMBER AIEE

G. E. MONCHAMP

MOTOR is no better than its rotor. Therefore, the
rotor should receive the same quality control attention
he stator and other elements.

ie-cast rotors have many advantages over the copper-
e rotors for induction motors but they also can have more
sible defects, because of the nature of the processing,
h as stray load losses, high-resistance or broken bars,
ng die-casting alloy, improper skew of the slots which is
icult to see in closed slot rotors, eccentricity of rotors, and
roper thickness of the bridges over closed slot rotors.
ese faults cause poor performance, and most of these de-
s can be tested for excessive noise.

hese defects can be detected by separate pieces of
ipment, both quantitatively and visually. It is desir-
e to test rotors prior to the final processing of the rotor or
l assembly of the motor. High production requires
t test equipment shall be simple and quickly operated.
ny high quality products require that die-cast rotors be
ed for all defects.

hown in Figure 1 is a front view of the complete test
ipment to check all rotor defects quantitatively and
ally. The unit consists of a motor driving the rotor to be
ed. Surrounding the rotor is a 3-phase test stator. The
or is driven in a direction opposite to that of the rotating
d of the stator. Around one tooth near the center of one
e of one phase of the test stator is wound an exploring
which is connected to an oscilloscope, shown on the
side of Figure 1. This phase is excited with direct
rent for visual tests.

n interlocked switch excites the 3-phase stator with
rnating current for the stray load loss and other quanti-
ve tests. The d-c circuit is open. Watt readings in the
e motor circuit correlate driving torque with stray load
es. Current readings in the test stator circuit detect
h-resistance bars or rings, large number of broken bars,
l skew. This test will not detect a small number of
ken bars. It is desirable to reject all broken bars from a
e standpoint.

ure 1. Complete
for testing die-
rotors visually
quantitatively

Broken bars and all other defects can be shown visually on the oscilloscope screen by opening the a-c circuit and closing the d-c circuit with rotor revolving. The d-c excitation of one phase produces only a pulsating current resulting from the rotation of the rotor teeth and bars. This in turn sets up a pulsation of the flux in the air gap by bucking down the primary flux. Each tooth or bar passing the exploring coil shows on the oscilloscope screen as a sine wave. When the sweep circuit of the oscilloscope is synchronized with the speed of the rotor teeth, a band of sine waves representing all of the rotor bars is shown on the screen.

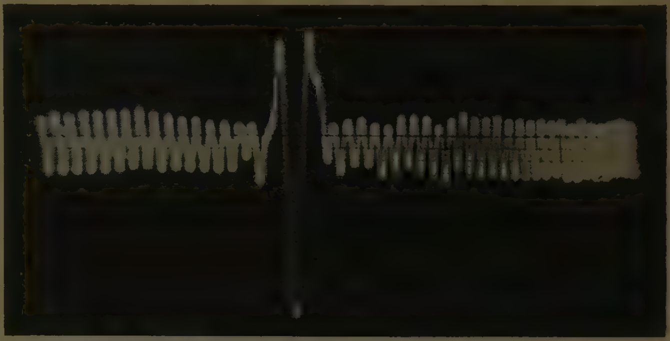


Figure 2. Die-cast rotor with one broken bar designated by high peaked wave

A good rotor of uniform resistance will have a wave band of uniform height. High-resistance bars will have lower current flowing in them; thus they have less effect in bucking down the primary flux. Therefore, the flux approaches a maximum peak value. Broken bars have no current flowing, therefore the primary flux reaches the maximum peak value, as shown by one broken bar in Figure 2. Stray load losses show up as a high modulated form of wave band. Other defects show up in the height of the wave band.

A synchronizing pulse is used when it is desired to show the location of the defect.

The combined test unit is operated at a rate of approximately 150 rotors per hour. The net result is better with more uniform performance, a more uniform flow of production, and a higher quality end product.

Individual visual test units have been used employing both permanent magnet and electromagnet with a pick-up coil to an oscilloscope and a synchronizing pulse. This type of unit is adaptable to all sizes and types of squirrel-cage motors.

Digest of paper 51-117, "Die Cast Rotor Studies," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Not scheduled for publication in AIEE *Transactions*.

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Noise Evaluation of Fluorescent Lamp Ballasts

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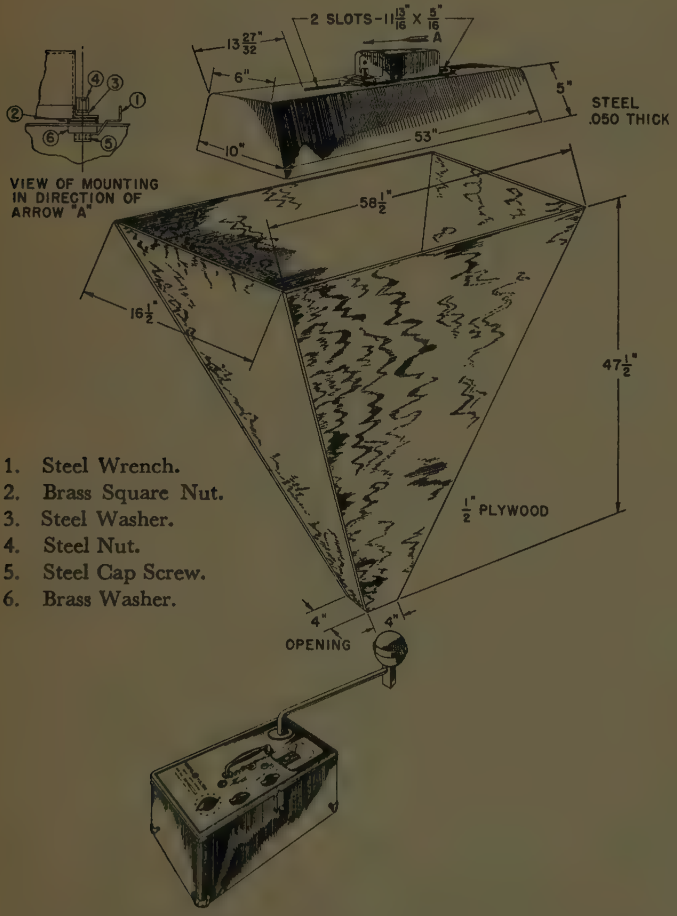
NOISE TESTING of fluorescent lamp ballasts has been studied from a number of approaches. A system has evolved from these studies which, if acceptable to the industry, may provide a basis for industry specifications and standards regarding this type of measurement.

The fluorescent lamp is a gaseous discharge device, and therefore must have an impedance or ballast connected in series to limit the current to the value for which the lamp is designed. Since many fluorescent lamps require starting voltages exceeding normal supply voltage, the ballast may also include a means for transforming the available circuit voltage. For 60-cycle a-c systems, the most efficient device for limiting the current is a reactor, and the usual device for voltage transformation is the transformer or autotransformer. The reactor or autotransformer, like other electromagnetic devices, is a source of audible radiation or noise.

Light sources such as the candle and incandescent lamp have been almost devoid of noise. The user of light, therefore, has not generally considered audible sounds or noise as a necessary component of lighting. The introduction of the fluorescent lamp brought an apprecia increase in noise to lighting of this type, so that the probl of noise reduction became very acute. The prim purpose for developing a noise measurement system was obtain realistic noise quality numbers which would def the noise characteristics of a fluorescent lamp ballast.



1. Steel Wrench.
2. Brass Square Nut.
3. Steel Washer.
4. Steel Nut.
5. Steel Cap Screw.
6. Brass Washer.

Figure 1. Construction details of the ballast noise test assembly

The early attempts to measure fluorescent lamp ball noise included ear listening tests, but a sound-level me was soon employed to determine noise levels. The of the sound meter provided numbers for ballast noi but it did not adequately define the characteristics of ballast as employed in field applications. Extensive no tests were taken with commercial fixtures which indica that the fluorescent lamp fixture in which the ballast mounted must be included in any noise evaluation of fluorescent lamp ballast. These early studies led to development of a dummy fluorescent fixture which wo respond to the noise generated by the ballast.

Since it was impractical to take a series of readi along the length of the fixture, a horn was fabricated fr plywood to collect or concentrate the noise produced by combination of ballast and fixture. A sound-level me was incorporated to detect the resultant noise, as sho in Figure 1. With this noise test assembly, the n generated by the ballast, amplified by the dummy fixtu and collected by the horn, was measured as decibels by sound-level meter. This noise test combination provi realistic data which would define the noise characteris of the fluorescent lamp ballast.

Modifications in the noise test assembly have been fou necessary to improve test procedures. Several varia have been encountered which must be carefully contro in this test. These have included ballast mounting on top surface of the dummy fixture, ballast temperature, fluorescent lamp operating temperature.

This test equipment, developed to evaluate the n characteristics of fluorescent lamp ballasts, has had seve important applications. It has been a valuable tool in evaluation of new designs and proposed methods reducing ballast noise. The test procedure is too leng for a 100-per cent production noise test, but it is suita for quality sampling tests. This measurement system by no means perfect, and it is hoped that others will this system so that further improvements may be possi

Some changes are to be expected, but is felt that measurement system has been developed far enough to considered by others who are concerned with the probl of ballast noise and its measurement.

Digest of paper 51-95, "Noise Evaluation of Fluorescent Lamp Ballasts," recomme by the AIEE Committee on Production and Application of Light and approved b AIEE Technical Program Committee for presentation at the Winter General Mee New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transac* volume 70, 1951.

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The Importance of Graduate Work in the Power Field

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Further graduate training, either in the colleges or in formal courses organized as part of industry training programs, are essential if the electrical engineer is to be prepared to meet the present and future problems of the electric power industry.

T IS the purpose of this article to discuss the education and training of ng engineers who enter electric power industry. ough the field includes y phases of industry and ufacturing, particular at- ion will be directed to the training of engineers for the lic utilities supplying electric power service and for the lication groups of the manufacturing companies which ly the equipment needed by the public utilities.

large measure, the engineering staffs of the public ties in the United States entered the industry in the de from 1920 to 1930. Most of these men were ge graduates and entered the industry after receiving bachelor's degree following a 4-year electrical engineer- course. On the basis of a normal retirement age of ears, which will be prevalent at the time this group es, these engineers will retire in the period from 1963 973. During the depression years and the years of ld War II, the additions of young engineers to these nizations were relatively few in number. With the inuing growth of the power industry, almost complete replacements and additions to keep pace with growth t be made so that trained staffs may be prepared to take the major engineering duties in a few years.

THE ENGINEERING GRADUATE OF 1925

CONSIDERING the present engineering group, the education of the electrical engineering graduate of 1925 be considered as typical. At that time, an educa- al program of four college years leading to a bachelor's ree was standard, and advanced work leading to a ter's or doctor's degree was extremely unusual. The ar graduate found himself reasonably well trained for problems of the power system which he encountered hat period. Although the curriculum at that time was considered to be specialized, it contained little or no ning in electronics and communication or radio, which n essential part of every electrical engineering cur- lum today. Furthermore, the emphasis on the broad- g of the outlook of engineering graduates has resulted ncreased emphasis on liberal studies and humanities he curriculum, with resultant decrease in technical ent. Thus, in comparison with the 4-year engineering iculum of today, the curriculum of the graduate of 5 would be considered a specialized one in the power . Upon entering the power industry in 1925, the electri- ngineer was frequently subjected to a training program of one year or more, conducted by the utility, or by the larger manufacturing companies. These training courses varied greatly, but included studies of the planning, design, and operation of the power systems of that day, and of the apparatus and its characteristics available at that time. Further training was for the most part accomplished by experience on the job, by attendance at technical society meetings, and by self-study.

GROWTH OF TECHNICAL REQUIREMENTS

IN THE YEARS which have intervened, the technical requirements of electric power systems have grown enormously. In 1925, reliable and accurate short-circuit analyses of power-system unbalanced faults were almost unknown. The methods of symmetrical components and similar related components by which these problems are solved regularly today were considered then the tools only of the advanced theorist. The entire technique of lightning protection involving the analyses of impulses and traveling waves, insulation co-ordination, and apparatus protection were unknown. Load and frequency control to a high degree of accuracy were dreams rather than realities. The concept of reactive power and the control of reactive power in voltage regulation was unknown. Protective relaying was confined largely to overcurrent relaying, and high-speed protective relaying was relatively unknown.

It is apparent to anyone familiar with power systems of the present day who has read the brief recital of engineering as viewed in 1925 that tremendous engineering developments have taken place. Although the present engineering staffs have met these developments effectively, and have applied them generally to power systems throughout the country, the necessary knowledge of new developments has been gained the hard way, and is not nearly as widespread or as thorough as it should be for the most effective utilization of engineering developments. Many engineers who could profit by knowledge of these developments have not had the opportunity for training in the advances that have taken place, and must rely on meager knowledge and half truths, and, in many cases, on the copying of practices of other utilities which may or may

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Essentially full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951.

Acknowledgment is gratefully made to E. R. Whitehead and E. T. B. Gross for assistance in the preparation of this paper.

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not be most effective for their particular problems. It seems almost self-evident that substantial improvements in power-system planning, design, construction, and operation could be effected if the public utility and manufacturing engineers were fully familiar with the important developments of the intervening years.

The knowledge and techniques applicable to power-system problems which have been developed over the past 25 years and which are continuing to develop at a rapid rate have frequently been given the name "Power-Systems Engineering," a term which is coming into more frequent use daily in the industry, in educational circles, and in engineer recruiting programs. If the young engineer being recruited today is going to be able to solve the power-systems engineering problems of the immediate future, it is essential either that he come equipped with education in this special field or that adequate training programs be set up to provide him with the specialized training and knowledge needed after his entry into the industry.

FUNDAMENTAL EDUCATION

IT IS AS true today as it ever was that the training of an engineer is never complete, and that he must continue to develop as long as he practices the engineering profession, if his work is to be crowned with a full measure of success. This means that the young engineer, as he leaves college, must not consider that his education is complete, but that he must plan to apply himself to the study of technical problems in the future as they are encountered. Thus, the education of the engineer is obtained only partly in college, and must be supplemented on the job throughout his career. The problem which confronts educators and those in industry responsible for personnel recruiting is to determine what part of the education should be completed in college and what part of the training should be developed on the job. It is usually agreed by both groups that the colleges should teach the fundamentals and the applications should be left to industry. However, such a decision does not solve the problem because it is then necessary to decide what is fundamental and what is applied education. The definition of a fundamental subject will differ widely from engineer to engineer, but many an engineer will define as fundamental all of the specialized knowledge needed to solve the technical problems of his present position. As the requirements of technical positions differ so widely, it is of course obvious that the composite fundamentals of all engineers in the public utility business would be beyond the scope of any college curriculum.

Nevertheless, there is a growing conviction that the fundamental preparation for power-systems engineering must include knowledge of some or all of these subjects:

1. The behavior of long transmission lines where the effect of distributed capacitance is important.
2. The basic behavior of impulses and traveling waves.
3. Electric transients in circuits and machines.
4. Symmetrical and related components for the analysis of unbalanced polyphase systems.
5. Power limits and the elements of power-system stability.
6. Basic lightning phenomena.
7. Electric fields and high-voltage phenomena, inclu ing corona and radio influence.
8. Principles of protective relaying.

Regardless of whether or not full agreement can be o tained on the preceding list of fundamental topics, it evident that almost none of them were included in th typical college education of the engineer who graduat 25 years ago. In the curriculum of today some treatme of the first three topics of the list usually is included, b the coverage is limited and often is arranged to stress t effects prominent at the higher frequencies of communic tion circuits. If the remaining topics are treated at a they usually must be elected as part of a limited option power which the larger colleges and universities may off but not more than one or two of these topics can be co sidered, even briefly, without the omission of broad and more fundamental topics usually considered essent in any engineering curriculum. Furthermore, beca of the time spent on basic electronics, communication, a radio, which were almost unknown in college curricu 25 years ago, and the increased emphasis on liberal studi the time available for polyphase circuits and transform and for rotating machines is almost surely less than it w then. Thus, in some respects, the graduate of today h a less thorough knowledge of topics of basic importance power systems than his fellow graduate of 25 years ag On the other hand, he is far better prepared in his know edge of electronics, communication, and radio, all which are making important invasions into power-syste engineering than the earlier graduate. In general, probably has a better knowledge of economics, accounti and finance, public speaking, and the humanities.

FUTURE EDUCATIONAL REQUIREMENTS

THIS ANALYSIS so far has been concerned largely wi power-systems engineering as it is today. With t current developments which are taking place at a rap rate, it is foolish to think that equally important develo ments will not take place during the next 25 years if t electric power industry is to keep pace with its need The engineers entering the industry today must be pr pared not only to meet the present problems but to sol the problems of the future by knowledge gained fro everyday operations in the industry. Therefore, it b comes increasingly evident that additional training mu be supplied to those young graduate engineers who are fulfill the important places in the power-systems field duri the next 10 to 25 years. With the new problems whi must be met, it is almost unthinkable that preparation meet the current problems must be acquired in the sa painstaking way it has been acquired in the past.

The alternative, and, for many of the subjects listed, t far more efficient way, is to provide training in organiz courses, given either as graduate work in the colleges as part of graduate training programs in industry. Whi of these two alternatives is adopted is not of vital importan The important thing is that either one or both of th alternatives be adopted and developed to the full. Y at the present time, few colleges and universities offer raduate training program in the power-systems engineer-g field encompassing satisfactorily all or most of the more ndamental topics listed previously. On the other hand, pid growth has taken place in graduate work in elec-onics, communication, radio, and radar. At the same me, few utility systems have augmented their programs include effective coverage of these subjects. In general, ly the larger utilities are equipped or can afford to evelop and offer training programs which are adequate r the needs. Thus, it seems evident that in many cases, the job is to be done, it must be done by the colleges, the form of graduate courses, leading perhaps to the aster's degree. In big cities evening graduate courses for mployed engineers can be used effectively but this will ot serve for those employed in the smaller cities.

This leads immediately to the next question: "Why do ot the colleges and universities do more about it?" The nswer is not simple, but a large part of the answer appears be the lack of an expressed demand on the part of the ublic utility industry for graduates with advanced train-g. The industry is not yet accustomed to seeking any ut the 4-year graduate. Yet, if the colleges are to do e job outlined in the foregoing in a satisfactory manner, is essential that the public utilities and manufacturers, their own interest, give recognition to the value of the aining required by recruiting engineers who have this aining and by offering salary inducements which will epay the student for the time and effort spent in obtaining year or more of specialized training.

Another reason for the lack of adequate graduate pro-rams in the power-systems field is the almost complete bsence of sponsored university and college research in the roblems of the electric-power industry. The opinion widely held today that the colleges and universities of e United States must carry on far more fundamental esearch than ever before, to continue and expand the evelopments and basic knowledge which, prior to World Var II, came largely from Europe. With the devastation f Europe, resulting from the war, progress of fundamental esearch in Europe has become almost nonexistent. Al-ough the United States has excelled in applied research nd development, most of the basic ideas of the past have een imported from Europe, and development to com-ercial fruition has been made by industry here.

NECESSITY FOR SPONSORED RESEARCH

TO PROVIDE adequate preparation for the future, expanded and augmented research of a fundamental aracter must be developed in the United States in an tmosphere free from commercial urgency and sales ressure. In many fields, extensive programs of funda-ental research have been developed since World War II ith industry, or for the most part government, sponsorship. remendous programs in electronics, servomechanisms, dio, television, guided missiles, and other phases of ectrical engineering have been developed, and the lleges have participated widely in these programs. On e other hand, little or no sponsorship has been provided y industry, the government, or anyone else, for the sup-ort of fundamental research seeking the solutions of problems confronting the power-system industry. Although it may be true that the problems of the industry are less acute and critical than problems in other phases of the electrical industry, there are many problems which are still unsolved. It is also true that many of the problems not solved satisfactorily in the power field involve more critical research by the chemist, metallurgist, or the physicist than research by the orthodox electrical power-system engineer. Nonetheless, the almost complete absence of currently sponsored research programs of interest to the power industry turns the young electrical engineer with an inquisitive mind, and, perhaps more importantly, his professors, to the more glamorous and immediate problems of other fields. The result is that the student whose turn of mind would inspire him to seek advanced training, in order that he might be prepared to solve research and development problems more adequately in his future career, turns away from power-systems engineering. Yet, in the long run, there are few in the power industry today who would admit that the industry does not require the services of the most competent engineers.

In other phases of the electric power field not discussed in detail the situation is similar. In nearly every phase, important technical developments have taken place with which the engineer should have a thorough knowledge, rather than a vocabulary acquaintance, when he enters upon his career. Yet the increasing diversification in education required by the development of the industry makes possible less penetration rather than more. Although improvement in methods of presentation and the elimination of less essential material have helped to keep pace, these factors alone are inadequate. For example, the development of automatic process controls and automatic devices in nearly all phases of industry requires that the competent industrial engineer be thoroughly familiar with transient phenomena, feedback control systems, servomechanisms, and magnetic amplifiers, as well as industrial electronics, all of which have important fundamental aspects that are best taught in organized classes and are not easily absorbed on the job. Yet none of these topics was included in the engineering curriculum of 25 years ago and there is little room for them in the 4-year curriculum of today. Similarly, a designer of large electric equipment in nearly every case requires a thorough training in the recent developments of heat transfer, and would profit greatly, for example, by further study of electric and magnetic fields and fundamental behavior of solid, liquid, and gaseous dielectrics. Yet any comprehensive treatment of these topics is beyond the range of the 4-year curriculum, and is not easily acquired.

There have been in the past, and will be in the future, many electrical engineering graduates employed in industry who do not require a high degree of specialized training. However, the day has arrived when the truly competent professional electrical power engineer has need for a group of fundamental subjects requiring more than the usual 4-year curriculum to provide them. Formal graduate training in adequately organized courses is essential to meet these needs. It is the task of the colleges and industry to work together in meeting them.

Mechanism for Hand Closing of Circuit Breakers

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IN THE ORDINARY application of power circuit breakers, the most desirable method of operation consists of d-c solenoid mechanisms for closing and tripping, supplied by a storage battery. When this is not suitable, the next choice is a dry metallic rectifier for closing from some a-c source and either current transformers or a capacitor device for a-c tripping. In some applications requiring only a single isolated circuit breaker, these methods of operation may not be desirable because of battery maintenance or because an auxiliary control transformer for a rectifier supply would have to be connected to the incoming line ahead of the circuit breaker.

On the other hand, direct manual closing of power circuit breakers is not desirable because of the relatively high force and speed required to make the operation safe in case the circuit breaker closes against a faulted circuit. This is particularly true of magnetic power air circuit breakers because the fault current may begin at a longer contact separation. Consequently, there is some need for a device to close magnetic power air circuit breakers without an external source of electric power.

A review of the possible means for doing this has led to a hand-charged spring device, which when released always closes the circuit breaker with proper speed and power. This method of storing energy in a spring gives reliable availability and may be arranged for simple operation.

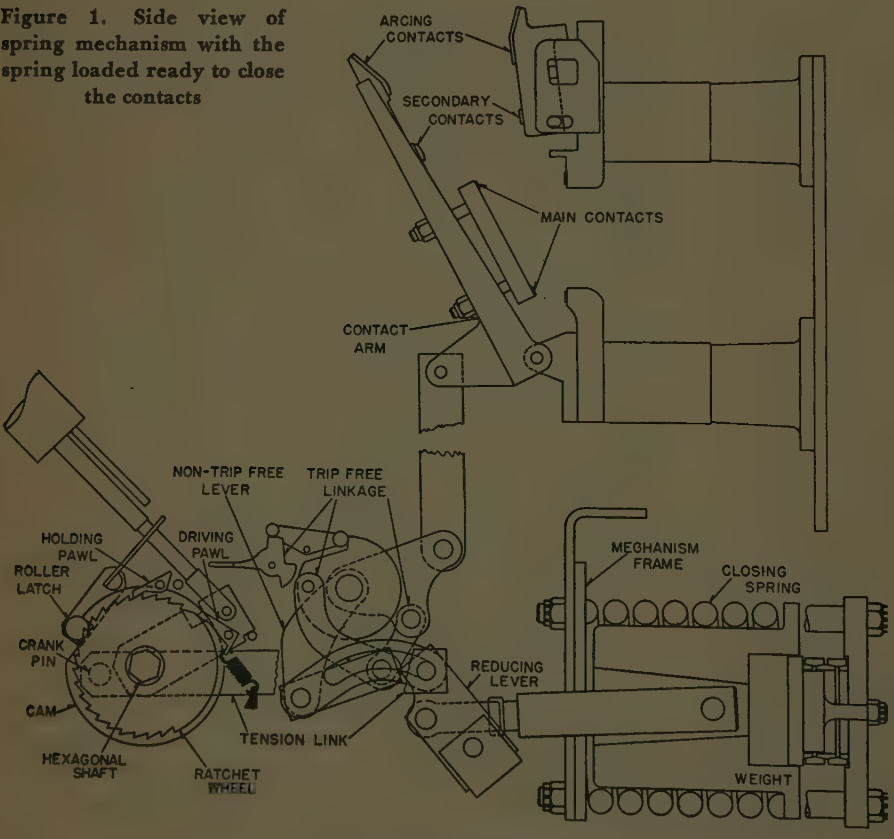

Figure 1. Side view of spring mechanism with the spring loaded ready to close the contacts

The force required to close most circuit-breaker contacts rises very rapidly toward the end of the closing stroke as the contacts touch. If a circuit breaker happens to be closed on a faulted circuit, large blowout forces may be added near the end of the closing stroke. Hence, in the actual design of a spring closing mechanism, the linkage between the closing spring and the contact arm must be arranged so that a relatively low force is delivered to the contacts at the beginning of the motion and a relatively high force at the end of the closing motion.

Figure 1 shows a side view section of such a device developed especially for magnetic power air circuit breakers that are applied almost exclusively in metal-clad switching equipment of the horizontal drawout type. The closing spring pushes against the frame of the mechanism at the left and against the weight on the right. In normal duty, this closing device is operated entirely from the outside of the metal-clad switchboard cell with the door closed. An escutcheon, built as an integral part of the device, extends flush with the outside of the closed cell door, with facilities for spring loading, tripping, and for visual indication o spring loading, circuit-breaker contact position, and number of operations.

Mechanical features are included in the device tha make its operation safe and simple so that a highly trained operator is not required. It has been designed so tha it is possible to close the circuit breaker slowly for inspection and maintenance operations and to leave the circuit breaker in the drawn out disconnected position with the cell door closed.

This device was designed for magnetic power air circuit breakers o 150 and 250 megavolt amperes at 4.16 kv and 150, 250, and 500 megavolt amperes at 13.8 kv. The maximum momentary rating among this class of circuit breakers is 60,000 amperes. Extensive tests in the East Pittsburgh high power laboratory were made in the development of this device. During the performance of these tests a current o 65,000 amperes at 4.2 kv was closed and latched successfully.

Digest of paper 51-25, "A Spring Mechanism f Hand Closing of Magnetic Power Air Circu Breakers," recommended by the AIEE Committee o Switchgear and approved by the AIEE Technic Program Committee for presentation at the AIE Winter General Meeting, New York, N. Y., Januar 22–26, 1951. Scheduled for publication in AIE *Transactions*, volume 70, 1951.

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Some Design Criteria for Automatic Controls

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THE EARLIEST, and most direct, method of analyzing automatic control systems is based on the solution of e differential equations of the system for some initial sturbance. This transient analysis is general and, emingly, may be applied to any problem which can be rmulated in differential equations. However, even with e aid of the powerful methods of the Laplace transrmation, synthesis of a complex control is largely a cutnd-try process.

In synthesizing a control, the problem, after stability achieved, usually is to choose the sensitivity factors, me lags, and inertias which will give as rapid a response disturbances as is consistent with reasonable deviations the controlled variables.

For many kinds of single-loop control systems the ethod of frequency analysis has been developed into a seful tool. However, some kinds of aircraft engine ontrols have two controlled quantities (speed and torque) nd two variables available for controlling (propeller tch and fuel flow). These quantities are interrelated ithin the power plant in such a complex way that the ansient analyses method seems to be the only way of ealing with the problem.

In the case of controls analyzed by the transient method, has been proposed that the "control area" be used as a esign criterion. If the response is known to be overamped, it is proposed to compute the area included etween the curve of a step function disturbance and the esponse curve and attempt to minimize this quantity. owever, many controls require a faster response, that is, ightly oscillatory, and further, the degree of damping btained in a control is one of the unknown quantities in e problem. In fact, the criterion of minimum control ea applied blindly is likely to produce a response which ecomes more violently oscillatory as the net area aproaches zero.

Contemplation of the overshoot in such an error curve ggests a more useful criterion than the control area. It an be seen that the initial error will always be present in any physical control systems, but the magnitude of the ror at later times may be minimized by suitable selection control sensitivities. Hence, study of an error curve eighted in accordance with some function of time would ad to a more useful criterion. One such weighted error rve would be simply t times the error.

The control area and the weighted control area can be alculated from the Laplace transform expression for the esponse to a unit step function change in setting. If the ansform of the response is

$$S)=\frac{1}{S}\,\frac{a_mS^m+\ldots\; a_2S^2+a_1S+a_0}{b_jS^j+\ldots\; b_2S^2+b_1S+b_0}$$

en the Theorem of Final Value can be applied

$$\lim_{t\to\infty} N(t)=\lim_{S\to 0} Sn(S)=a_0/b_0$$

provided that $b(s)$ is such that the system is stable, that is, has positive damping. This can be determined from the Routh-Hurwitz criterion without finding the roots of $b(S)=0$.

If it is desired that the control eventually reach the new setting, then $a_0=b_0$. With this proviso, the error is $N(t)-1$ and the "control area" is

$$A_{10}=\lim_{t\to\infty}\int_0^t [N(\tau)-1]d\tau=\lim_{S\to 0} S\left[\frac{n(S)-1/S}{S}\right]=\frac{a_1-b_1}{b_0}$$

provided the system has positive damping.

The weighted control area may be obtained by a similar method and is

$$A_{11}=\lim_{t\to\infty}\int_0^t \tau[N(\tau)-1]\,d\tau=\lim_{S\to 0}\; -S\left[\frac{1}{S}\,\frac{d}{dS}(n(S)-1/S)\right]$$

or

$$A_{11}=\frac{(a_1-b_1)b_1-(a_2-b_2)b_0}{b_0^2}$$

provided the system has positive damping, and that $a_0=b_0$.

These quantities are simple functions of the coefficients of the transform expression and depend only on the coefficients of the S^2, S, and constant terms. This is not surprising as these coefficients contain the products of all the roots of $b(S)=0$, taken in various groupings.

For design purposes $A_{11}=0$ is often used but leads to a somewhat underdamped response (in a second order system, the damping ratio would be 0.5). However, the ratio $R=A_{11}/(A_{10})^2$ has the property of being almost independent of b_0 and hence of the product of all the roots, and a value of R which gives a very satisfactory control is $R=-1/2$. This gives a damping ratio of 0.7 in a second order system.

Some classes of regulators are intended to reduce the system response to zero following a step disturbance.

In such a case we may have:

$$n(S)=\frac{1}{S}\,\frac{c_mS^m-\ldots\; c_2S^2-c_1S-c_0}{b_jS^j-\ldots\; b_2S^2-b_1S-b_0}$$

and $c_0=0$ to give the proper final value. The control area is then:

$$A_{00}=c_1/b_0$$

and the weighted control area is:

$$A_{01}=\frac{c_1b_1-c_2b_0}{b_0^2}$$

provided that $c_0=0$ and the system has positive damping.

Digest of paper **51-99**, "Some Design Criteria for Automatic Controls," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Further Development of Fluid Mapper

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FLUID MAPPERS are fluid-flow devices for visually simulating electrostatic, electromagnetic, heat conduction, and other analogous situations. The writer has described fluid mappers in his first[1] paper on the subject, and it is called the "first paper" herein.

Before Hele-Shaw's work of half a century ago, it was known that an ideal (nonviscous) fluid flowing within suitable boundaries theoretically could simulate electrostatic and other fields. At any one location, the ideal fluid's velocity, taken across the flow space, would be constant, whereas, with a real (viscous) fluid in streamline flow, there would be a parabolic velocity distribution. Hele-Shaw was the remarkable pioneer who showed that, nevertheless, the real fluid also would give accurate simulations if the flow space were made thin enough. Hele-Shaw's methods were not carried on; though remarkably accurate, they were costly and inflexible.

In fluid mappers developed by the writer, the upper plate (of plate glass) is retained. But Hele-Shaw's lower plate is replaced by a slab of artificial stone (dental stone) cast on plate glass to make it flat. Also, the writer's invention of the sandbed as a distributed source carries the fluid mapper into the extremely complicated realm of distributed source phenomena.

Dental stone powder costs only 15 to 20 cents a pound. Thin slabs a few inches across may take only a pound; larger slabs, up to a foot square, may take four pounds. With some plate glass, a tray, two or three tanks, some rubber tubing, some brass pieces for molds and barriers, some potassium permanganate, some dental powder, and a few other knickknacks, anyone, for a few dollars, can set up a fluid mapper laboratory for demonstrating a great variety of cases. By adding some screen material and shotted metal, sandbed types of mappers become available.

Fluid mapper techniques are well enough developed so that many fields can now be simulated accurately by applying tested routines to building and operating the mappers. Like all other devices, they have their own special problems, troubles, and limitations. Further invention, research, and development of additional techniques are needed.

Fluid mappers as now developed fall into three main types, all represented in Figures 1 and 2.

At the right in both figures is a slab without a sandbed—the first type. The sources are simple wells of any shape or size. The bottom-up view, Figure 1, shows the plaster feet added to the plaster slab, the celluloid well bottom plastered on, and the connector tubes plastered into the well bottom. Anyone can soon learn to make such sla

The second type, at the left in Figures 1 and 2, is operate as a slab with a sandbed. A screen is mount horizontally across the well, to support the sandbed, wi a plenum chamber below it.

The third type, at the top in both figures, is the isolat sandbed, or sandbed without a slab. Between the botto and the screen is the plenum chamber, and the sandb is built above the screen.

A complete fluid mapper of the first type is in operati in Figure 3. The two wells are acting as sinks, their tan being nearly empty, with the right tank lower than t left. Figure 4 shows a flow pattern obtained with th setup, the tank levels being the same.

Figure 5 shows the pattern made with a mapper of t second type. The entire round sandbed area is acting a uniformly distributed sink. The sandbed margin is an isopressure line. This is very different from Figure wherein the edge of a well acts as a boundary, or an i pressure line.

The third type, an isolated sandbed, is shown in Figure Here, the boundary of the sandbed is an isopressure li as it is open to the tray water.

The foregoing serves to describe the general nature fluid mappers. Space is not available here to descri numerous techniques for ma ing and operating mapp in routine fashion. Ma were covered in the first pap Since then, the writer h continued the developme work. Earlier techniqu have been improved, so have been replaced, and n techniques have been p fected. These will be incluc in a manual or book on fl mappers and field mapping, now in preparation. V little can be said here about the various analogous fi phenomena that fluid mappers can be made to simula For this, the first paper may be consulted; also the secon on soap film and sandbed techniques; and the third,[8] which fluid mappers serve to verify certain electromagne propositions.

PURPOSES OF THE ARTICLE

TECHNIQUES now well developed will serve for mak and operating fluid mappers for portraying an mense variety of the more ordinary situations. In paper and in every other way, the writer wishes to courage all who want to get some experience with fl mappers. Their potential value in solving field probl

Essential text of paper 50-267, "The Further Development of Fluid Mappers," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Published in AIEE *Transactions*, volume 69, part II, 1950, pages 1615–24.

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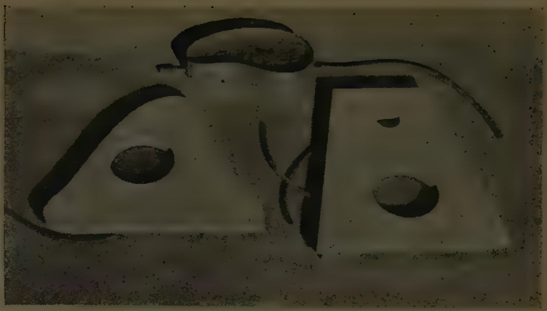
Figures 1 and 2. Bottom (left) and top (right) views of the lower members of the three types of fluid mappers. The upper member, the plate, is always plate glass



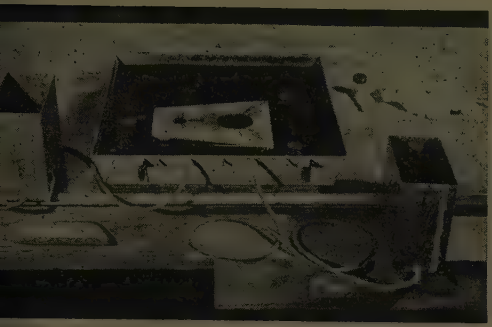
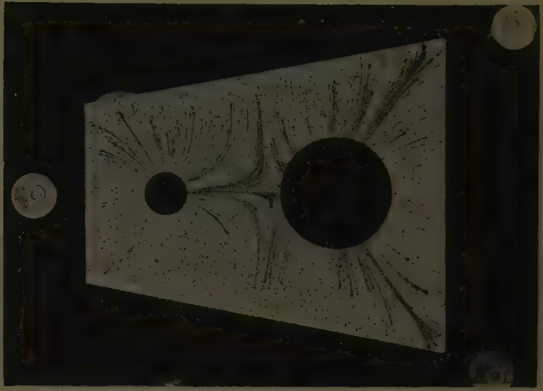


Figure 3 (left). A complete fluid mapper of the first type in operation

Figure 4 (right). Direct view of flow pattern. To produce this pattern, the tank levels were made equal



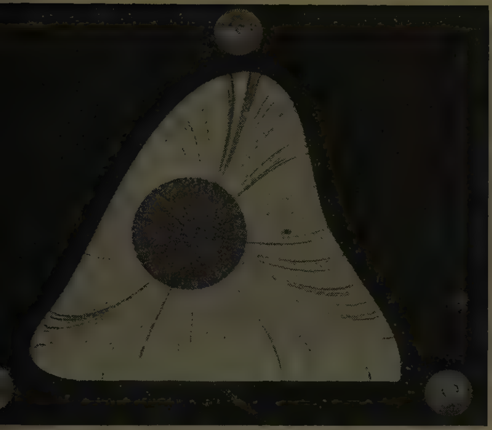
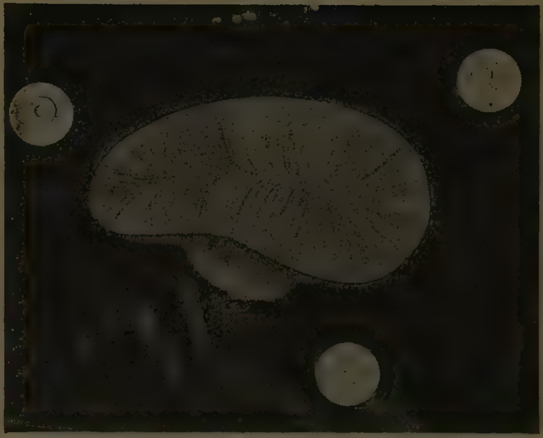


Figure 5 (left). A mapper of the second type, a sandbed within a slab. The sandbed here acts as a uniformly distributed sink. Note the kernel

Figure 6 (right). An isolated sandbed, a fluid mapper of the third type. Note the kernel and the ridgeline



their great value as teaching tools warrant experi-
ation on a wide front.

the same time, it must be recognized that fluid
ers, like all other devices, have their inherent errors,
ts, and limitations. By describing some of these,
purposes are served. First, those who are making
mappers will learn something of how to avoid trouble,
minimize its effects. Second, further invention,
rch, and development on fluid mappers are needed in
to remove the present handicaps. Graduate students
thers will find a number of research problems herein.

PROBLEMS

b Permeability. Slabs made of dental stone are
ly permeable, and there is always a little fluid leakage
gh the slab. All experience strongly indicates that
effect is completely negligible; but nevertheless, it
d be measured to make sure.

b Erosion. This is not mechanical erosion. It is disappearance of slab face material due to its going into solution. Calcium sulphate, the main ingredient, is slightly soluble. The rate of erosion has not been measured. It appears that greatest erosion occurs where flow space velocities are highest. Something should be known about erosion rates in order to know how long a slab may be used before being discarded or resurfaced. For accurate work, new uneroded slabs can be used.

Erosion might be stopped by saturating the water with calcium sulphate. This has not been tried. Treatment of the surface to form insoluble calcium stearate, and use of soft soap to form calcium oleate, have been suggested. The writer has used Spred Satin, a synthetic rubber emulsion paint, to stop erosion. However, with its use it was discovered that with permanganate used for dyelines, a permanent pattern record was formed. The erosion problem needs further attention.

Slab Resurfacing. Flat slabs can be resurfaced quite easily. A large sheet of waterproof silicon carbide cloth, grit number 100 (Minnesota Mining and Manufacturing Company) is placed face up on plate glass. A little water is poured on it. The wet slab, face down, is skated around on the cloth with a random motion. After flushing off the ground plaster and wiping off the water, a piece of plate glass is pressed to the face. Where good contact occurs, a water film appears. A good distribution of such areas seems to indicate flatness. However, all this should be looked into further and checked.

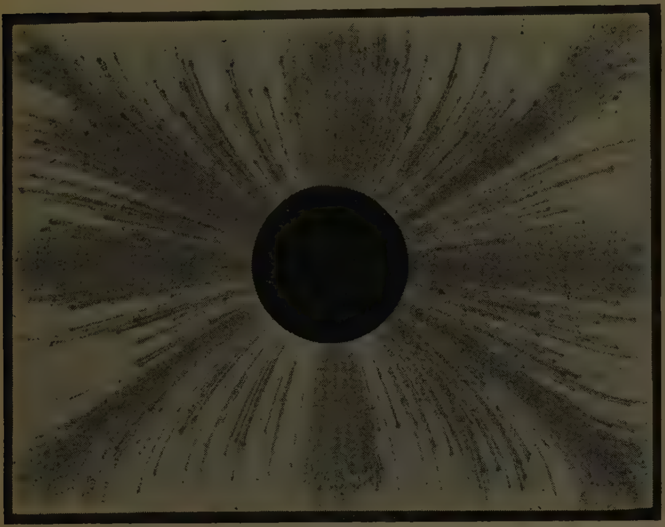


Figure 7. Permanent record slab made with potassium permanganate crystals on a slab covered with Spred Satin

Slab Materials. Plaster, so far, is the prime material for slab making. The writer's early slabs were made of patching plaster. Plaster of Paris would do. These, along with dental stone (artificial stone), are basically calcined gypsum. These are all plasters, even though the dental product is called stone in dental circles. Duroc, the newest dental stone, is the smoothest and hardest; its setting expansion is only 0.05 per cent. With all the numerous things that can be done cheaply and easily with plaster, this material is most attractive.

However, plaster erodes, and some attention should be given to developing plastic or metal slabs for permanent purposes.

Very Large Slabs. The writer's largest slabs are one foot square. The same routines would turn out slabs up to 18 inches square, and perhaps 7/8-inch thick. However, still larger slabs may be needed, and problems of distortion may be encountered. The plate glass on which the slab is cast may bend, unless adequately supported; the slab might need extra supports to maintain its own flatness in operation; and in operation extra spacers may be needed for the top plate. Techniques might be worked out for casting a large slab in sections and placing the sections edge-to-edge.

Record Slabs. Excellent permanent record slabs are easily made. Spred Satin, made by The Glidden Company, Cleveland, Ohio, is painted onto the wet slab face
after excess water is mopped off. In a few minutes
paint is set well enough to permit operation. By sprink
with the potassium permanganate crystals a "floor patte
is formed; the dye lines are on or close to the floor of
flow. A chemical reaction quickly takes place.
record slab, Figure 7, was made on December 9, 1
It is as clear and sharp today as when it was new.

The problem here is to change the painting job fron
art to a science. Brush painting is somewhat tricky,
irregularity of thickness sometimes changes the flow s
enough to cause error.

Record slabs are very beautiful. As to use, they m
fine teaching aids, and they often eliminate photogra
The slab can be traced directly as soon as the recor
formed.

Fluids. The writer has used air as the fluid, but
smoke formed by reacting hydrochloric acid droplets
the plate with ammonia fumes diffuses too much to f
a sharp pattern.

Tap water holds first place for demonstrations, an
serves for accurate work in many cases. However, ine
effects may enter in to spoil the desired streamline
when pattern velocities are made high enough to make
pattern sharp. This is the case in Figure 8, where
break-away point is very close to the wing tip. In Fi
9, velocities have been reduced to where inertia effe
practically eliminated, and the break-away point has m
back to where it would be if a heat-flow field were b
simulated. However, the pattern is somewhat va
too much lateral diffusion of the dye occurs at the red
velocities.

The way out of this dilemma is to go to a fluid of
viscosity. Hele-Shaw used glycerine, but that is c
The fluid of choice today is water with Methocel, a
Chemical Company product. Methocel, a cellulose e
is a nontoxic colloid. Two per cent by weight of the
known as "Methocel 1500 centipoises" in water giv
viscosity of around 1,500 times that of water. It then
be diluted.

Investigation with a variety of mappers should be ca
out varying shapes, flow space thickness, and visc
It would be desirable to know in advance something a
the viscosity needed to eliminate inertia effect.

Pattern Levels. Crystals resting on the slab form a
pattern. It is a "slow" pattern, as velocities near
floor are low. Diffusion of the dye sometimes resul
lack of sharpness of pattern.

The crystals can be stuck to the plate with Cute
form the beginnings of a ceiling pattern. The dye
then sink somewhat, thus getting into higher vel
levels; by moving faster, they diffuse less, and ofte
very sharp lines.

When methylene blue crystals and permanganate cr
are attached to the plate, side by side, it is found tha
tendency to sink is very different for the two dyes.
flow rate is lowered until the permanganate line dro
the floor in 1/4 inch of travel, the methylene blue lin
carry along high and sharp for many inches.

Much work needs to be done on the dye-line pro

t may be that one or two other dye crystals suitable
appers may be found.

es and Dye Effects. Potassium permanganate is cheap
safe to work with; its stains are easily cleared up;[1]
t is the best dye for most fluid mapper purposes.
ethylene blue gives much sharper lines; it is safe to
with; but its stains are not removable. The hunt
ethylene blue in crystal form must go on.

dye undoubtedly affects viscosity, but there is no
nce that this is serious. Again, this effect should
ve research attention.

vancing Dye Front. If permanganate dust is stirred
a tank feeding a source, the precolored water entering
ow space demonstrates an advancing dye front. The
is striking, and it may have a meaning which might
und useful. This effect should be investigated in fur-
detail.

w and Potential Control. When the problem has such
erties that definite rates of flow of sources and sinks
be set up, this can be done by using connector tubes
librated resistance and adjusting the heads accordingly.
design can be handled so that flow space resistance can
nored, or nearly so.

the other type of problem, given potentials at sources
sinks and boundaries must be simulated; this would
or setting up predetermined isopressure values at these
s, which is not easy to do. The techniques have not
worked out, and the apparent difficulties involved
easuring pressures may not yield to effort along this
Instead, a series of cases can be set up, a partial
sis of each pattern made, and data secured for a
that will indicate the fluid mapper setup to use.

Edge Effects at Isopressure Boundaries. In much fluid mapper work it is safe to assume that an isopressure line is coincident with the edge of a well or with the open edge of a slab. However, this is not strictly so, and the departures should be investigated. Also, when a well is small in width compared with the flow space thickness, there can be a considerable departure from coincidence. Such problems ask for attention.

Edge Effect Along Barriers and Obstacles. Where flow in the flow space is bounded by an obstacle or barrier, another edge effect occurs because fluid velocity at the barrier is zero. In the first paper[1] it is suggested that when necessary, this be approximately compensated for by "cutback," that is, by cutting back the barrier (or obstacle) from where it otherwise should be by an amount equal to one-fourth of the flow space thickness. Even so, there are flow phenomena in this region needing consideration. For example, at which level should the pattern be set up to get the truest simulation?

Stability. The use of a thin flow space is required for two reasons. One is to minimize edge effects. The other is to secure stability. With too large a space the fluid wanders, and patterns at different levels will not coincide. No one as yet knows anything about the upper (stable) limit of flow spacing for a given case.

Swirl effect[1] occurs when fluid enters from a small source (or shoots into a well from the connector tube) rapidly enough to alter the pattern in the nearby flow space. Crowding gauze into the lower part of the well will cure the difficulty. Other means of control of this inertia effect would be welcome.

Disturbing Influences. Local disturbances are caused by

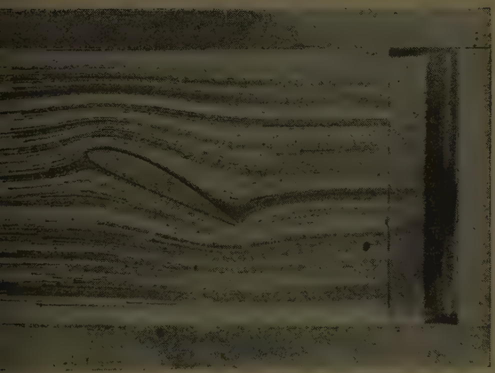


Figure 8 (left). With velocities high to get sharp pattern lines, inertia effects moved the break-away point nearly to the wing tip

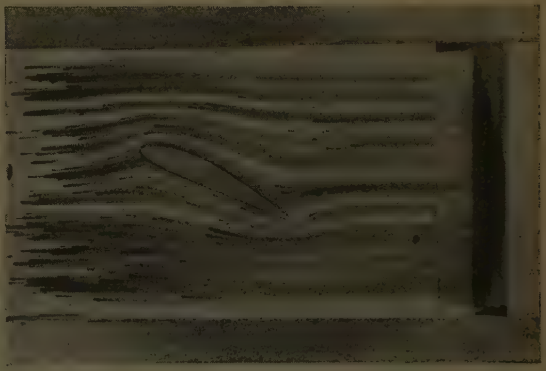


Figure 9 (right). With lowered velocities, the inertia effects drop out and laminar flow prevails. Lines are more diffuse

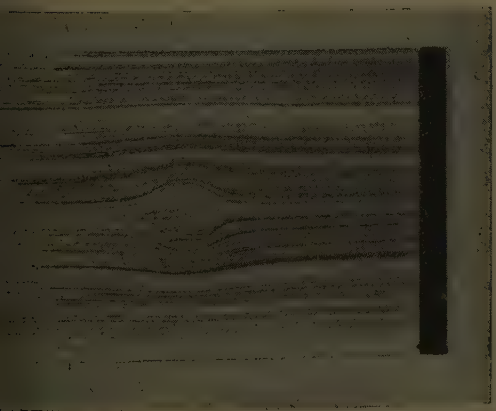


Figure 10 (left). A semiobstacle case with flow spacing two to one, representing permeability or conductivity ratio of eight to one

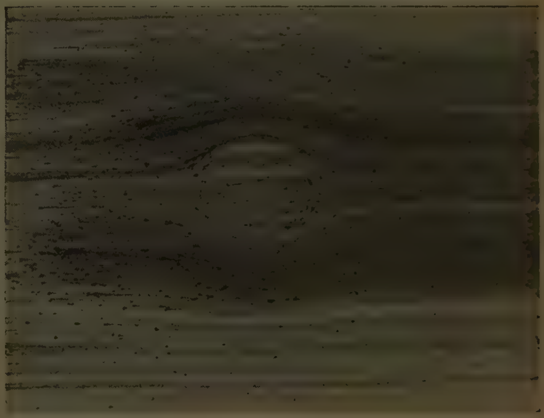


Figure 11 (right). A closer view of the semiobstacle pattern

placing crystals in the flow. If permanganate is used, it is doubted if sprinkling is ever heavy enough to disturb the general pattern seriously. Nevertheless, this definitely calls for research. Another kind of disturbance occurs when a slab of infinite size is needed, but one of finite size must be used. How near to the central phenomena can the edges be brought without seriously affecting the central pattern?

Barriers. Loose barriers (movable) are easily cut from rubber sheet. But such sheet varies in thickness. With a complete barrier leakage is almost certain to occur unless *DC4* silicone grease is used for sealing.

Loose barriers for many purposes are also made from brass strips made from 1/16-inch stock.

To insure accuracy and no leakage, the writer has developed the fixed barrier. The slab is cast flat, as usual; then a plaster barrier is added by appropriate techniques.[4]

Depressions. Two media having different constants may be simulated by making a depression in the slab. The depression can be milled in. Techniques for casting the depression should be worked out.

Semiobstacles. The airfoil section of Figure 8 is a complete obstacle; all flow goes around it. With a semiobstacle, Figure 10, flow partly goes around and partly goes over or under it, depending on whether the attached piece is placed on floor or ceiling. The effect is the inverse of that obtained by using a depression. Simple, reliable, and accurate techniques for making semiobstacles are needed very much. In Figure 10, a piece of celluloid was attached to the plate with acetone. This is an easy way to make a good demonstration, but accuracy cannot be achieved in this way.

Change of Flow Space More Generally Considered. When two or more media must be simulated, at least two of which take up more than a small part of the area, the modification of slab or plate to modify the flow space accordingly may be quite a task. Of course, a flat slab can always be milled down; but faster and simpler techniques are needed.

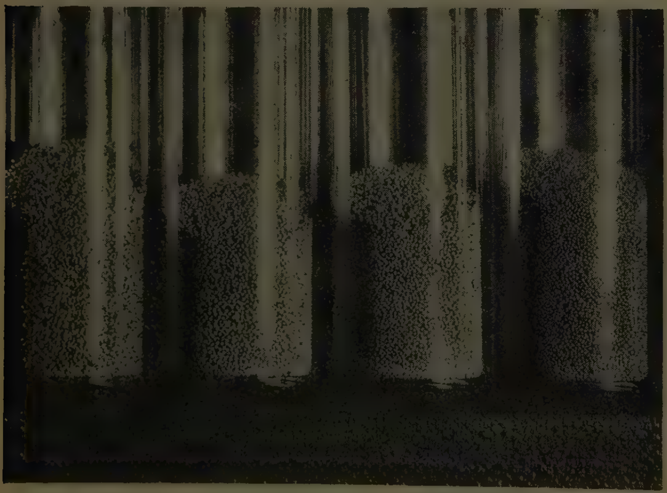


Figure 12. Shotted metal samples. Left to right: tin, bronze, copper, nickel. Tin and bronze are not suitable for sandbeds because of angularity

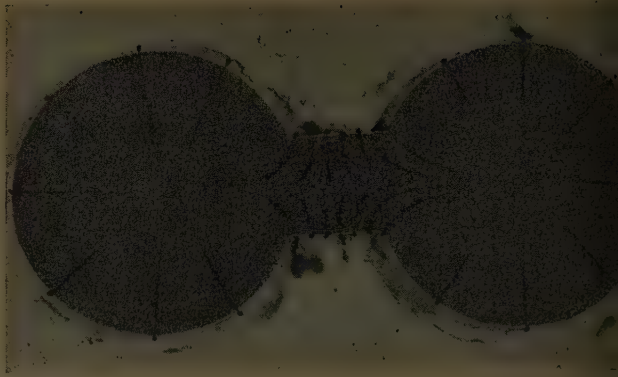


Figure 13. The point of inaction, shown in the bar o dumbbell. Nickel shot used in the sandbed

Axial Symmetry Cases. There are two types of ax symmetric cases. For one, the flow space varies dir with the cube root of the radius; for the other, inve with the cube root of the radius. So far, the writer milled and scraped such slabs. If a terraced slab (mi without scraping) would do, one operation would out. This should be tried.

Quasi-3-Dimensional Cases. If the flow space is kept enough to insure stability, but otherwise is varied at problems of this character could be solved: flow uniform sheet, having nonuniform resistivity; flow nonuniform sheet, having uniform resistivity; and combination of these. Here again, the terraced slab inviting prospect.

Sandbed Materials. All of the writer's sandbeds (re senting distributed sources) are now made of sho metal, either nickel or copper. Floaters are avoide using Aerosol *OT* as a wetting agent. The metal gra for a sandbed should be heavy, round, smooth, br stable, and of uniform size. The ideal shotted meta sandbeds has not been found yet.

Shotted Metal Sandbed Problems. Four kinds of r granules are identified in Figure 12. The tin and br are angular, and worthless for sandbeds as they wil pack uniformly. Nickel is best, even though darker copper; it is smooth, round, and nearly uniform. it is not available commercially.

Shotted copper is none too round; it lacks uniform and it has many irregular particles. Segregation threat. It can make fine sandbeds, but must be se into place with care.

The sandbed presents several interesting packing lems, each of which would bear investigation.

Sandbed Flow Space Relationships. With existing niques, reliable sandbeds can certainly be built operated. However, there are several interesting rela ships between grain size, sandbed depth, plenum cha depth, sandbed area, flow spacing, and so on, that sh be worked out so that safe limits could be establishe applied to the design of sandbed types of fluid mappe

Nonuniform Sandbeds. The nonuniform distributed s can be simulated by use of a nonuniform sandbed.

everal obvious ways for modifying the sandbed, not of which has as yet been tried out. All should be ed on, and techniques established.

dbed Plenum Chamber. The inclination is to make lenum chamber below a sandbed much deeper than be. A simple practical test is available for finding her the chamber is deep enough. But here again, rch is needed to guide design to the safe side.

e Kernel, and Lines of No Work. An apparent center n a distributed source or sink where the lines seem nverge is clearly seen in Figures 5 and 6. This point lled the kernel. Next, consider the flow lines in re 5 and interpret electromagnetically; the sandbed represents a conductor section with uniform current ity. Outside of the section the flow lines represent potential lines, but inside (over the sandbed) they esent "lines of no work." These phenomena, and names, are well recognized. They are mentioned in order to lead up to two other distributed source omena not so well known, the ridgeline phenomenon the point-of-inaction phenomenon.

he Ridgeline Phenomenon. Distributed source fields are ery difficult that few solutions have ever been made, very few good maps have been available. Until bed mappers became available, there was no simple to set up a case so as to look directly at the complete representation. Thus, such phenomena are quite miliar to most. One phenomenon is very striking n it appears under certain conditions. It is a distinctive line, with the kernel located on this line. Such a line occurs in Figure 6, and it might be thought of as a "distributed kernel." The writer proposes to call it ridgeline.

The Point-of-Inaction Phenomenon. The writer has built sandbeds in which flow from one region tends to meet flow from another, with the meeting place over the sandbed itself. Such a meeting place, if happening outside of a source, results in what we call a singular point. There is then the temptation to call such a place, within a source, a "singular point within a source." Instead, it is here proposed to call it a "point of inaction." This phenomenon may not have been recognized. One case of it appears in Figure 13.

INVESTIGATIVE SANDBED WORK

THEORY ALONE can never yield much insight into phenomena within distributed sources except in the simplest cases. Since sandbed fluid mappers visually simulate these exceedingly complex situations, it may follow that fruitful experimental work might be done with sandbeds to gain insight and discover additional phenomena.

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Study of Nuclear and Electronic Magnetic Resonance

K. K. DARROW

Since the discovery of magnetic resonance in solids, liquids, and gases in 1945, the phenomenon has been used in the determination of nuclear magnetic moments and magnetic field strengths, as well as in the study of crystal structure and relaxation times.

HE TITLE of this article might have been "Magnetic Resonance olids, Liquids, and Gases." reader may think that last five words of this rnative title are superus and that it would have better to say "Magnetic Resonance, Period." If he ks this he is overlooking what has been called "the th state of matter" but is more commonly called "the molecular beam." Molecular beams are streams of atoms or molecules crossing a vacuum all with about the same speed and in about the same direction. Their importance in this connection is that magnetic resonance was discovered in experiments on molecular beams. The discoverer was I. I. Rabi of Columbia University, and the date of the discovery was the winter of 1937–38. Now having done historical justice to Rabi, I confine the remainder of this brief account to molecular resonance in solids, liquids, and gases.

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ext of a conference paper presented at the AIEE Winter General Meeting, New N. Y., January 22–26, 1951. First in a series of two papers on magnetic materials h frequencies.

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In this limited sense, molecular resonance was discovered at the end of 1945. The discovery was made, simultaneously and independently, at both ends of the United States: by Felix Bloch and his group at Stanford University and by E. M. Purcell and his group at Harvard University.

It is not very often that any discovery in physics makes such a great and immediate sensation. In their impact on physicists, the initial papers rank with Bohr's first publication of his atom model, Schroedinger's first on his wave mechanics, the discovery of fission, the discovery of the positive electron, and a very few more. This was because the theory is basic and very simple, and the phenomenon clean-cut and very striking. Before displaying the phenomenon I will give a brief description of the apparatus as it was set up in some of the experiments of Purcell.

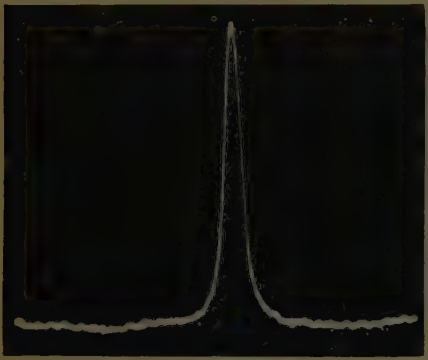

Figure 1. Proton resonance peak obtained with water containing ferric nitrate

Illustrations courtesy *Physical Review*

The sample—let us here think of a tube of water for definiteness—is immersed in a strong and constant magnetic field between the pole pieces of a powerful magnet. The field strength will be denoted in what follows by H; for definiteness the reader may hold in his mind a value of 10,000 gausses. Around the sample is wound a coil upon which is impressed an alternating voltage of radio frequency. The symbol for the frequency shall be ν, and its order of magnitude tens of megacycles for nuclear resonance and thousands of megacycles for electronic resonance. Measurements of the impedance of the coil show that absorption of radio-frequency energy is taking place in the sample; it is possible to calculate the absorption, and to plot it as a function of ν when H is held constant (or the other way about).

When absorption is thus plotted against frequency for constant H, one finds a smooth curve. This is of no importance in the present connection. What is of importance is that under the right conditions the smooth curve is interrupted by a magnificent peak, high and sharp enough to be called justly a needle. This is the phenomenon of magnetic resonance. There is probably nothing else that appeals to an experimenter or, for that matter, to a theorist as much as does a curve presenting a high sharp peak. Here they find it, as Figure 1 (for nuclear resonance) and Figure 2 (for electronic resonance) portray. Indeed, the peak of Figure 1 is narrower by far than the reader probably suspects. This is because he naturally assumes that the origin of co-ordinates and the axis of ordin
are somewhere near the left-hand side of the figure. A
ally they are 15,000 times as far away toward the le
the peak is wide—and this is not even the narrowest
which has been observed; it is one of Purcell's earl
and it is shown here for its historical interest. Som
Purcell's peaks had a breadth less than 0.15 gauss, with
field strength of 7,000 gausses; even this minimal brea
was ascribed in part to inhomogeneities which were
ent in the field.

Turning to the theory, water consists almost altoge
of three kinds of particles: nuclei of ordinary hydr
atoms, which are called protons; nuclei of ordinary ox
atoms; and electrons. The oxygen nuclei are nonn
netic and produce no resonance. The electrons are
magnetic and yet produce no resonance, for a reason w
will be mentioned later.

Beginning with the protons, each proton is to be visual
as a tiny bar magnet, of fixed and permanent magn
moment, hereinafter to be denoted by μ_p. The valu
μ_p is known from experiments of other kinds, and there
may be taken as a quantity established in advance of
experiments. This magnetic moment may be orie
in various directions, and of these we will take two.
is the direction into which the magnetic field H would
to turn the tiny magnet, and, in fact, would turn it if
proton were a compass needle. Suppose that the s
pole piece of the magnet is above the north pole pi
then this particular orientation is the one in which
north pole of the proton is turned up and the south
down. It is called the "parallel" orientation. The o
is the orientation in which the north pole of the pr
is turned down and the south pole up, and it is called
"antiparallel" orientation.

Now the amount of work which must be done upo
proton to turn it from its parallel to its antiparallel orie
tion must be calculated. This is easy to do by clas
methods. Let θ stand for the angle between the direc
of the proton and the direction of the field; θ is zero
the parallel orientation and 180 degrees for the antipar
The torque on the proton is $-\mu_p H \sin \theta$. The work w
it is desired to compute is the integral of the torque
θ equals 0 degrees to θ equals 180 degrees. The integr
is simple, and the result is:

$$\text{Work} = 2\mu_p H$$

Now one of the basic doctrines of quantum th
must be invoked. This is the doctrine that when er
is absorbed from electromagnetic waves of frequen
it is absorbed in units or parcels or quanta equal t
Here h stands for Planck's Constant, of which the val
very well known from experiment. It is unfortu
that in the theory of magnetic resonance both capit
and lower case h must be used, but it would be wo
one were to change either symbol. Thus we co
equation 1 into the following:

$$\nu = 2\mu_p H/h \quad \text{(proton)}$$

and this equation embodies the theory of magneti
onance for the proton. The frequency of mag

ance, for proton-containing substances, is given by ion 2; if it were otherwise this article would not been presented. For a field strength of 10,000 es it is located at 42.6 megacycles per second.

rning from the proton to the electron, the equation agnetic resonance of the electron is equation 2 with ubstitution for μ_p of μ_e, the magnetic moment of the on:

$$H/h \quad \text{(electron)} \qquad (3)$$

magnetic moment of the electron is about 700 times of the proton, so the resonance must be sought at a spondingly higher frequency; or if one wants to e it at the same frequency, the magnetic field H must educed correspondingly.

wever, magnetic resonance of the electron cannot be l in water, nor indeed in most substances. This is use of a quantum-theory law which may be parased roughly by saying that in most substances the rons behave as though they were rigidly coupled her in pairs and the members of each pair were ted in opposite directions. Thus, each pair of elec- forms a nonmagnetic whole on which both constant alternating fields have no effect. To find the electron nance substances belonging to either of two classes in h this coupling does not occur must be used, or to ess it better, substances in which some of the electrons ncoupled.

ne of these classes is that of the strongly paramagnetic For these the electron resonance is located at the ency given by equation 3; it must be mentioned, ever, that often there are several peaks instead of one, easons too deep to expound here.

ne other class is that of the ferromagnetic metals and s. For these, equation 3 is incorrect because the inside a strongly magnetized substance is not identical the applied field H. There is, in fact, a quantity d "induction" and denoted by B, the exact interpreta- of which is rather baffling, but at least it is measurable. not intuitively obvious whether in equation 3 H ld be replaced by B or by some combination of B H. Kittel, however, developed the theory, and showed equation 3 must be replaced by the following equation:

$$_e\sqrt{BH}/h \qquad (4)$$

erromagnetic substances the electron resonance is ally found very nearly at the frequency given by tion 4; the small discrepancy can be explained by profound theory.

ne applications of nuclear magnetic resonance are dy numerous, and brief mention will be given to only v.

a nuclear physicist, one of the most interesting uses agnetic resonance is the determination of nuclear netic moments. In this application μ is the unknown quation 2. Some 40 nuclear moments have already measured in this way. Among them may be listed moment of the proton itself, for although μ_P had pre- sly been measured by other methods, this one is the accurate by far.

To an experimental physicist in or out of the field of nuclear physics, magnetic resonance of a nucleus of known moment—preferably the proton—affords an excellent way of measuring magnetic field strengths. In this application H is the unknown in equation 2. This method, already much in use, compares well with the older methods and in many cases is superior.

Magnetic resonance may also be applied to the study of crystal structure. Considering a substance containing protons, each proton is subjected not only to the applied magnetic field H but to the magnetic fields of its neighboring protons as well. These are much weaker than H, but they are not quite inappreciable, and they bring about a broadening or a shifting of the resonance peak from which the distance from any proton to its nearest neighbors may be calculated. Remember that protons cannot be located by diffraction of X rays, since they do not scatter X rays sufficiently. Magnetic resonance and the diffraction of neutrons furnish the only methods by which the locations of the protons in a crystal lattice can be determined. In liquids the resonance peak is likely to be narrower than in solids; this is true because the rapid motions of the nuclei—protons in water, for instance—blot out the effect just described.

Measured by volume of literature, though not necessarily when measured by other criteria, the study of relaxation times is the major application of magnetic resonance. This affords a pretext for delving deeper into the theory.

Returning to the case of protons in water, it may have been surprising that allusions have been made only to the parallel and the antiparallel orientations. It was permissible to ignore the others because the others do not exist. This is an illustration of perhaps the strangest of all the laws of quantum theory; it is, however, not only strange but also well attested, and one of the proofs is precisely the fact that magnetic resonance peaks are so

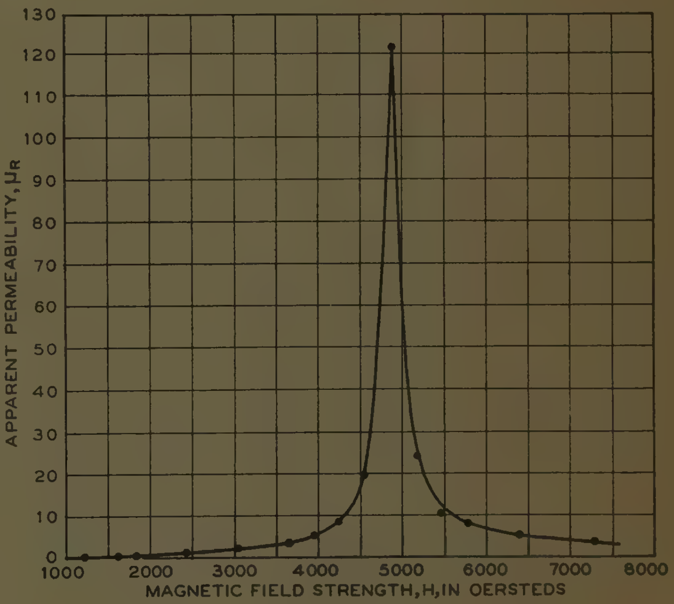

Figure 2. Electron resonance peak in annealed Supermalloy

extremely narrow and are located just where equation 2 says that they should be. In a sample of water in a magnetic field, all of the protons are either in the parallel orientation or in the antiparallel. Boltzmann's Law tells us how they are distributed between the two when thermal equilibrium prevails. It turns out that in thermal equilibrium at room temperature, out of 2,000,000 protons seven over 1,000,000 are in the parallel orientation and seven under 1,000,000 are in the antiparallel state. Not very much of a margin, and yet it is responsible for the whole effect, and (according to the theory) if this margin were to vanish the resonance peak would vanish along with it. Is there any experiment by which we can make the margin vanish or at least diminish, and in such a manner test the theory?

On examining this question we readily see that not only is there such an experiment but it is an experiment which is performed automatically whenever a resonance peak is measured. Consider the sample of water continually exposed to both the steady field H and the radio frequency. Every time a radio-frequency quantum is absorbed, a proton is turned from the parallel orientation into the antiparallel. It comes back eventually, but it does not come back right away, and until it comes back the margin is reduced correspondingly. Thus the height of the peak diminishes as the experiment goes on; this has been verified.

The height of the peak varies with time as $\exp(-bt)$. If it is wished to restore the peak to its original height, the radio frequency is turned off while leaving the steady field in operation, and thereafter the radio frequency is turned off only from time to time and only just long enough to measure the height of the peak. The height of the peak then varies with time as $(1-\exp[-bt])$. The constant b, which is measured in such experiments, is a measure of the rate at which the protons get back to thermal equilibrium with the steady field H after their equilibrium has been disturbed and then the disturbing factor has been removed. Its reciprocal is called the relaxation time. It depends on many things: the type of nucleus which is involved, the neighboring nuclei, the crystal structure or lack of it, the temperature, and others. Known values of relaxation time range from several hours down to very small fractions of a second. For all except the longest times the measurement cannot be made by the method described; the relaxation times are deduced from the widths of the resonance peaks. The peak exhibited in Figure 1 was not obtained with pure water but with water mixed with ferric nitrate; the solute diminished the relaxation time and sharpened the peak.

The closing paragraphs of this article have been reserved for what may well be deemed the most important quality—most important in this connection—of nuclei and of electrons. This is the angular momentum, otherwise known as "spin." It is important because it is responsible for the singular law of orientation which, in turn, is responsible for the sharpness and indeed for the existence of magnetic resonance. The law of quantum theory operates on the spin, and in the cases of the proton and the electron constrains it to point either in the parallel or in the antiparallel orientation. The magnetic moment is just drag
along to follow the spin.

Since the spin has been designated as the most import
quality of proton and electron, the reader may well won
why it did not figure in equation 2 or equation 3. It d
figure in both, but it is concealed in the factor 2. T
proton and the electron both have the same value of s
(and this, incidentally, is the only feature that they h
in common). This is the smallest nonzero value of s
that any particle may possess. Its numerical value
pends on the unit of spin chosen, and if $h/2\pi$ is chosen
the unit, then the value common to both proton and el
tron is 1/2. This is the reciprocal of 2. The factor
which $\mu H/h$ is multiplied in equations 2 and 3 is
reciprocal of the spin value of proton and electron, wh
$h/2\pi$ is chosen as unit of angular momentum.

There are many nuclei having other values of spin,
of which are integer or half-integer values of 1/2; th
range as high as 9/2. For any of these, equation 2 is
be rewritten, with the reciprocal of the appropriate va
of spin put in place of the factor 2.

The symbol p is introduced to stand for the spin of
nucleus, expressed in terms of $h/2\pi$ as unit. The gene
equation then is

$$\nu = (\mu/p)H/h$$

and this shows that what is really measured, when
magnetic-resonance peak is located, is the ratio of μ t
This is called the "gyromagnetic ratio." Thus, w
magnetic resonance strictly gives us is a way of measur
not the magnetic moment of the resonating particle
itself, but the gyromagnetic ratio of the particle; and
is how the reader will find the method described, norm
and correctly, in the literature. However, the pract
difference is slight, since usually the value of p is kn
from experiments of other types.

I add two more statements for the benefit of those
wish to pry further into the theory; others may ign
them. First, when the particle has a spin greater than
the number N of permitted orientations is greater tha
the equation is $N=(2p+1)$. This does not result in
appearance of more than one peak; absorption alw
involves the passage of a particle from one orientatio
an adjacent orientation, and equation 5 remains corr
The second statement I will illustrate from the case
proton and electron ($p=1/2$, $N=2$). According to
newest form of quantum theory the spin is not 1/2,
$\sqrt{(1/2)(3/2)}$. The "parallel" orientation is not str
parallel, but slanted to the field direction at such an a
that the projection of the spin on the field directi
1/2; the corresponding assertion is made about
"antiparallel" orientation. Equation 5 retains its vali
Those who wish to pursue the topic furthur may study
articles by G. E. Pake in the *American Journal of Physi*

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A New Lightweight Rapid Transit Motor

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ASSOCIATE AIEE

BROADENING application field for the President's Conference Car (PCC)-type electric car has intro- ed new and more severe requirements in the design of propulsion equipment. This has resulted in a new tion motor embodying the latest progress in design manufacture, and particularly suited to dynamic king at the high operating speeds currently coming vogue. The application of the PCC car to high-speed rban service, and the utilization of the same pro- ion equipment for lightweight rapid transit service, e set the stage for a redesign of this equipment to meet new performance demands. Whereas a speed of 35 s per hour was rarely exceeded in city service, speeds of miles per hour and above may be expected in rapid sit and suburban operation. Coincident with the ease in top speed is the requirement that dynamic king be made available from these speeds without ry to the motor from overvoltage.

he new motor is designed to meet the above conditions to incorporate other improvements resulting in more ormance per pound of weight. An increase in the ber of commutator segments and a shortening of the allow an increase in the dynamic braking voltage. inements in the mechanical construction render the new or better able to withstand the centrifugal forces erienced in high-speed operation.

he new motor shown in Figure 1 is rated 55 horsepower 300 volts. The frame is suitable for the same truck unting as the earlier motors. The characteristics are that cars equipped with these motors will have the e operating characteristics as present cars equipped the earlier motors.

he commutator is of the archbound design instead of Veebound previously employed. This change is in ord with the modern trend in motor design, and is a ly desirable improvement. In addition, the segments steel parts have been strengthened to better withstand -speed operation. The commutators are seasoned repeated cycles of heating and cooling while revolving igh speeds, followed by tightening.

he use of wedges has replaced the core binding wire holding the windings in the slot. This eliminates the ding losses and also provides greater mechanical ngth. Skewed slots are employed to minimize magnetic e. The armature shaft, which can be replaced without urbing the windings or commutator, has been increased liameter to add stiffness for high-speed service. Hot- king of the core on the shaft has dispensed with the t keys. The omission of the commutator key permits ore accurate line-up of commutator segments with the slots.

earing assemblies have been simplified to facilitate ntenance without sacrificing performance. The commutator end ball bearing, which locates the armature longitudinally, is carried in a cartridge-type assembly that fits into the bore of the framehead. The pinion end is fitted with a roller bearing to take up longitudinal movement of the armature. When the armature is removed, the complete bearing assemblies are removed with it, a feature that prevents the bearings themselves from being exposed to dirt. The armature conductors themselves are insulated with Permafil-treated glass, and the ground insulation is mica and glass.

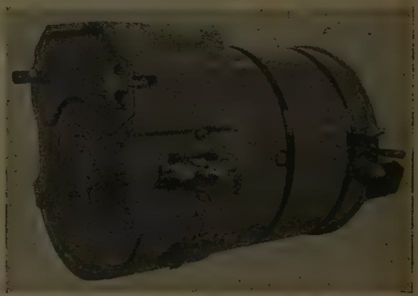

Figure 1. New 55-horsepower 300-volt d-c lightweight rapid transit motor

The most significant contribution offered by the new motor is in the extended range of dynamic braking.

Below 40 miles per hour and down to approximately $1^1/_2$ miles per hour where dynamic braking begins to fade, the maximum braking effort is obtained with full field strength on the motor. Since the generated voltage on full field is directly proportional to speed, some means must be employed to hold the value within practical limits as speed is increased. The determining factor in arriving at the maximum desirable braking voltage is the volts developed between commutator bars. Experience has shown a value of 40 peak volts per bar to be the practical operating limit for 0.045-inch commutator side mica. In order not to exceed these limits when operating at speeds from 40 miles per hour up to the maximum of 58 miles per hour, field shunting is employed to reduce the generated voltage while holding a constant value of load resistance across the motors.

A test car equipped with the new motors has been operating for some months in high-speed suburban service in the city of Shaker Heights, Ohio, transit system. The performance of this equipment over the maximum speed range in both motoring and dynamic braking has given conclusive proof of the success of the design, and established the significant contribution which the new motor will make towards the development of modern transit systems.

Digest of paper 51-31, "A New Lightweight Rapid Transit Motor," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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D-C Power Supplies

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THE PROBLEM of obtaining selective tripping of feeder circuit interrupters on d-c traction systems is an old one which has challenged the ingenuity of design engineers for many years. The ideal operating condition is one that keeps the feeder circuit breaker closed under all conditions of normal loads and quickly opens the interrupter when a short circuit occurs on its circuit, all other interrupters remaining closed.

Overcurrent tripping, because of its simplicity and speed, is an ideal method for clearing faults so near to the substation bus that the ratio of fault current to maximum load current is large. Overcurrent devices alone are inadequate for discriminating between normal loads and short circuits which are far enough from the substation bus to have current magnitude less than that of normal loads. For protection against the large proportion of faults that are of this latter class, tripping devices based on current rate-of-rise were developed and have been used successfully for many years. However, the application of such devices has relied largely on staged short-circuit tests and operating experience. Recently such a device, consisting of an impulse coil and d-c relays, has undergone extensive laboratory tests. Performance data have been developed to put the application and setting of the device on a definite basis comparable to a-c relay practices.

The impulse coil design is similar to that of a current transformer. The chief difference is that the iron core broken up by a series of air gaps to prevent saturation load currents. The relays associated with the second circuit should respond equally well on short circuits wheth the fault occurs under no-load or full-load operation.

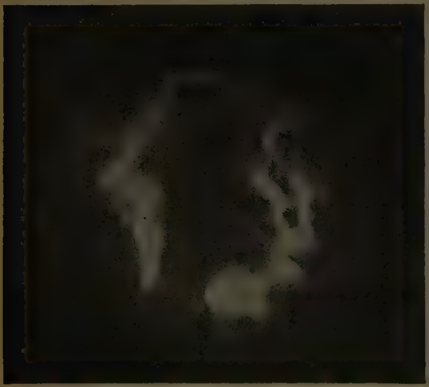

Figure 1. An uncontrolled 20,000-ampere 750-volt 12.5-millihenry arc

Figure 2. A controlled 20,000-ampere 750-volt 12.5-millihenry arc

Two types of relays are used with the impulse co The *S* relay is a fast operating solenoid type with a bias winding to prevent tripping in case of a sudden drop load current. It is used to quickly trip the feeder int rupter for nearby faults when the rate-of-rise is fas than that caused by normal car or train acceleratio The second relay, type *D*, is of the moving coil type w an electromagnet energized from the station cont battery. The moving coil, with a fixed calibrati resistor connected in parallel, is in series with the *S* rel coil in the impulse transformer secondary circuit. F remote short circuits where the fault current takes a long time to reach its maximum value, the secondary curre causes the relay to close its contacts and trip the int rupter. On car or train accelerations, the relay m start to operate but will not travel far enough to cau tripping. Thus, it is possible to segregate heavy loads fro short circuits and only trip the feeder interrupter und the latter condition.

Theoretical calculations of any traction system may readily made from data now available. Relay settin may be made initially from these calculations as the feed are put in service. Final adjustments then are made fro the operating log record. The initial relay settings made on the low or tripping side so that the adjustmen if necessary, are made in the direction of nontripping

Most traction systems have considerable inductance the d-c feeder circuits. The circuit interrupters produ large volumes of ionized gases which are readily direct to harmless areas. If they are not, they can cause sh circuits with damaging effects. Much improvement the technique of gas handling has been made in rece years.

Since the negative side of the d-c circuit is grounded most traction systems, the structures surrounding positive circuit interrupter should either be left isola from ground or grounded through a ground protective re with an operating coil of high resistivity. This precauti is safer to both personnel and equipment.

In unattended substations, service continuity dema the use of automatic reclosing apparatus so that the fee interrupter may be safely reclosed as soon as the sh circuit is cleared.

Digest of paper 51-90, "D-C Power Supplies and Isolation of Faults on Electric Tr Systems—Part I," recommended by the AIEE Committee on Substations and appr by the AIEE Technical Program Committee for presentation at the AIEE W General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for public in AIEE *Transactions*, volume 70, 1951.

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Engineering Must Have Prestige

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E VERY ENGINEER has a job to do that is not directly related to the project that he is working on, but which is important to the prestige of the engineering ofession. That job is to let the layman know what he doing, why he is doing it, and what the results would be ne failed to do it. In other words, publicity is an extra-rricular part of an engineer's responsibility.

A popular topic of conversation among engineers is the atively low professional status of engineering. Almost ways they will agree that the engineering profession not accepted by the public as a profession in quite the me way as are the professions of medicine and law, and soon as this conclusion is reached they feel a little sorry themselves and cast about for reasons why the profession not so well esteemed.

If the engineers can succeed in being objective about eir profession and if they can look at the problem from nontechnical point of view, they can usually think of a mber of reasons why the public is not placing them ite on a par with the other professions. They usually y that the term "engineer" is misapplied; that engineer-g training is not right because it is too specialized or ere is not enough time spent on cultural subjects and the manities; that most doctors and lawyers work directly themselves while most engineers are employees. If the scussion is carried on to its conclusion, it usually ends th a decision that there are several things that "they" eaning the profession at large) ought to do.

While I do not agree that the state of affairs is quite as d as many engineers seem to think, I do believe that the al reason for what lack of appreciation there is lies not much in failures of the societies as in the failures of our-ves to publicize ourselves and our work. I believe it is important part of our business to let people know what stand for and what we are doing. I believe we can this by being better mixers.

Engineers are not accepted as they should be because public does not know about them, and the reason for is is that the engineers have not bothered to tell them. gineers usually pay little attention to publicity because ey are absorbed in their work. Because they know how portant their work is, they take it for granted that the blic knows it also.

Engineers depend too much on the societies to do the blicity work for them, and when they find that publicity s not taken root they are inclined to blame the societies. this they are mistaken. The societies cannot do ich of the needed publicity work; it can only be done dividually by the engineers themselves. The doctors and the lawyers automatically get this job done because they work directly for the public and in the public interest. The engineer works just as much for the public interest, but more indirectly. Instead of working on his client's health or prestige, the engineer works on machines or devices or constructions that will themselves affect the public health or prestige. His work stands between him and his client. As a result, the public is apt to forget the personality behind the work, particularly if that personality remains hidden under a table of 7-place logarithms.

An important thing to remember is that it is not just for personal prestige or gain that engineers have a responsibility to keep their profession before the public. There is another reason far more important than that.

This is an age of engineering. Engineering has brought our civilization into existence and directed our way of life, and our civilization is sustained by engineering. It will take more engineering, perhaps much more than we think, to keep our civilization going in the future. Engineering must be able to attract our best men, our most public-spirited men. *The engineering profession must have prestige.*

Because our civilization and our way of life are so dependant upon engineering, it is essential that engineering be well represented in shaping public policies and in planning for the future. More public leaders must arise from the ranks of engineers. When engineering does get the prestige that it must have, the public will begin to look to the engineer for leadership.

The following comment recently appeared in a New York paper: "In a predominantly engineering civilization, a civilization surrounded and sustained by the work of the engineer and incapable of living an hour except for his efforts, it is remarkable how few engineers ever reach public prominence. We duly honor our poets and statesmen, our philosophers and soldiers and scientists, but we seldom know who our engineers are."

I am firmly convinced that the only reason why the public does not know who its engineers are is that the engineers have not bothered to tell them. It is not because the people are not interested. It is not at all because the work of the engineer is too technical. It is not because many of us work for an intermediary between us and our clients. It is mainly because we are content to remain out of the public view, because we would rather associate with our technical societies and our long equations. It is because we have too much of a tendency to feel that our accomplishments will do our publicity work. I believe the time is ripe for the engineer to step forward and to take the place of leadership in a technical world that is rightfully his, a place that only the engineer can fill as it should be filled.

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ential text of an article which originally appeared in *DODS*, newsletter of the Doings he Denver Section of the AIEE.

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A Full Automatic Private Line Teletypewriter Switching System

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A full automatic teletypewriter message switching system has been developed for use in private line networks involving one or more switching centers and a multiplicity of local or long distance lines, each of which may have one or more stations. This system provides fast teletypewriter communication from any station to any other station or group of stations in the network.

IN THE YEARS before World War II a number of private wire teletypewriter systems had grown to considerable size—some of them spanning many states or even the entire country. About 1940 it was felt that a faster, more economical service could be secured by the use of automatic switching of teletypewriter messages, and the Bell Telephone system undertook the development of fully automatic arrangements. In October 1941 a full automatic teletypewriter switching system was placed in service for the Republic Steel Corporation, just in time to handle the rush of war business.

World War II prevented the installation of additional systems of this type and interrupted the development program. Experience with the Republic Steel system during the war proved not only its many advantages but the soundness of its basic features. Following the war, a wide interest in teletypewriter switching systems of this general type resulted in further studies and the renewal of the development program.

The studies indicated the need for even greater scope and versatility with such new features as the use of more than one switching office in a system and the full automatic handling of multiple address messages which are messages originating as a single transmission to be delivered to more than one receiving station. As a result of the development program the present system known as the *81C1* teletypewriter system was produced and placed in service for five large customers with nation-wide networks.

The *81C1* system provides efficient, accurate, and rapid handling of a continuous flow of messages between the various stations on extensive private line teletypewriter networks involving a multiplicity of lines and stations. It functions in such a manner that a message may be sent from any sending teletypewriter and recorded on any desired receiving teletypewriter or group of teletypewriters in a network without requiring manual handling or operating attention other than the original perforation of tape at the sending station and the removal of the typed message from the receiving machine or machines to which it was directed. The switching erations are entirely au matic and are under the co trol of directing charact punched at the head of ea message in the original tra mitting tape and end- message characters punch at the end of each messa

Individual line circu are full duplex and may operated at either 60 or 75 words per minute, thus p mitting maximum economies for any line loading.

The general objectives considered and met by the desi include efficient usage of line circuits, rapid delivery messages, and accurate handling of traffic, as well as ma other customer requirements dictated by their individ traffic patterns and problems. Different sizes of switchi offices, the number of switching offices in a system, number of trunks between switching offices, the numb of stations in a system, the amount of traffic for lo delivery in the vicinity of a switching office, the quant of multiple address traffic, and a number of other variati must all be considered when a system is engineer The traffic which industrial systems must handle co sists, in general, of relatively long messages which must transmitted over the systems with speed and accura On the other hand, traffic for transportation compani particularly airlines, consists, in general, of much shor messages, a high percentage of which must be transmit over the systems within very short intervals. The desi of the *81C1* system anticipated these variable factors a permits the installation of systems which provide for th without special engineering for each case. Figure 1 sho an example of an *81C1* network now in service.

The Ford Motor layout is an example of a system wh one very large switching office at Dearborn handles traffic. In this case (see inset) there is a large volume local traffic to be distributed to stations within a sh distance of the switching center. Other large layouts operation today show the versatility of the system.

Pan American Airways has a system in which there three widely separated areas, each with its own commu of interest. Each area is served by a switching office w lines radiating to stations in the area. Single trunks tween switching offices at San Francisco and New Y and between New York and Miami are sufficient to ca the traffic between the areas.

Eastern Airlines has a system in which there are centers with a community of interest, each served b

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Essentially full text of paper 51-76, "A Full Automatic Private Line Teletypewriter Switching System," recommended by the AIEE Committee on Communication Switching Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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hing office. In this case there is sufficient traffic een the switching offices at Atlanta and New York arrant two trunks between them.

neral Motors has a system where one large switch- ffice located at Detroit is best adapted to handle the c. In this case, the heavy volume of business for the quarters office is delivered at the switching center and ibuted principally by telephone, messenger, and pony

ne Western Electric Company uses a large industrial m in which there are two major centers of traffic in York and Chicago served by two switching offices. large amount of traffic between these offices necessitates oup of interoffice trunks.

GENERAL METHOD OF OPERATION

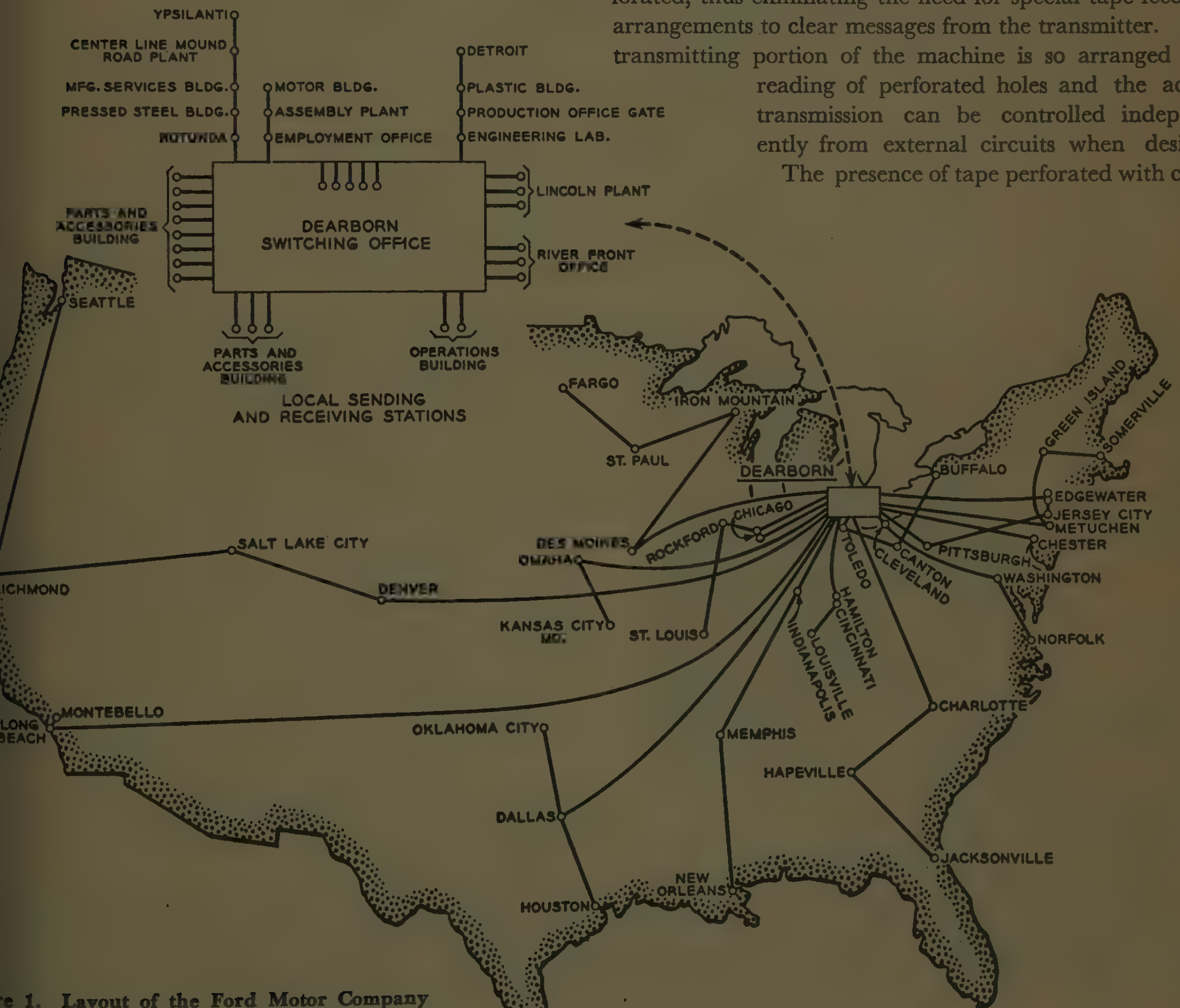
CH STATION in the system is assigned a 2-letter code, and in order to direct a message from any sending on in the system to any receiving station, the operator rates in the sending tape the 2-character code of the ed station followed by a "Letters" signal. Of the 26 rs of the alphabet 20 are used for station code pur- s, thus permitting up to 400 station codes. The letters), *M*, *V*, *H*, and *Z* are not used for various reasons. The first four are apt to be produced in case of an accidental interruption or hit on an idle line, while *H* and *Z* are used for other switching functions which will be explained.

Referring to the block diagram, Figure 2, the path of a message first will be traced from a sending station which has exclusive use of a line (1) (numbers in parentheses indicate locations on block diagram of Figure 2). The message is perforated in a tape at the station, the text of the message being preceded by the 2-character code of the station of destination and followed by the characters, "Figures," *H*, "Letters," which indicate the end of a message. This tape is sent from the transmitter distributor which may be seen in Figure 3. No further action on this message is required on the part of the station operator.

The incoming line circuit (2) at the switching point associated with the line serving this station perforates the message in a tape on the receiving side of a reperforator-transmitter (3).

The reperforator-transmitter shown in Figure 4 is a machine which forms the heart of the switching system. This machine consists essentially of two parts, a receiver which perforates and prints tape identical with the tape made at the station, and a transmitter which transmits the signals represented by the perforations in the tape and which is so arranged as to transmit the last character perforated, thus eliminating the need for special tape feed-out arrangements to clear messages from the transmitter. The transmitting portion of the machine is so arranged that reading of perforated holes and the actual transmission can be controlled independently from external circuits when desired.

The presence of tape perforated with char-



e 1. Layout of the Ford Motor Company m with a switching center at Dearborn, Mich.

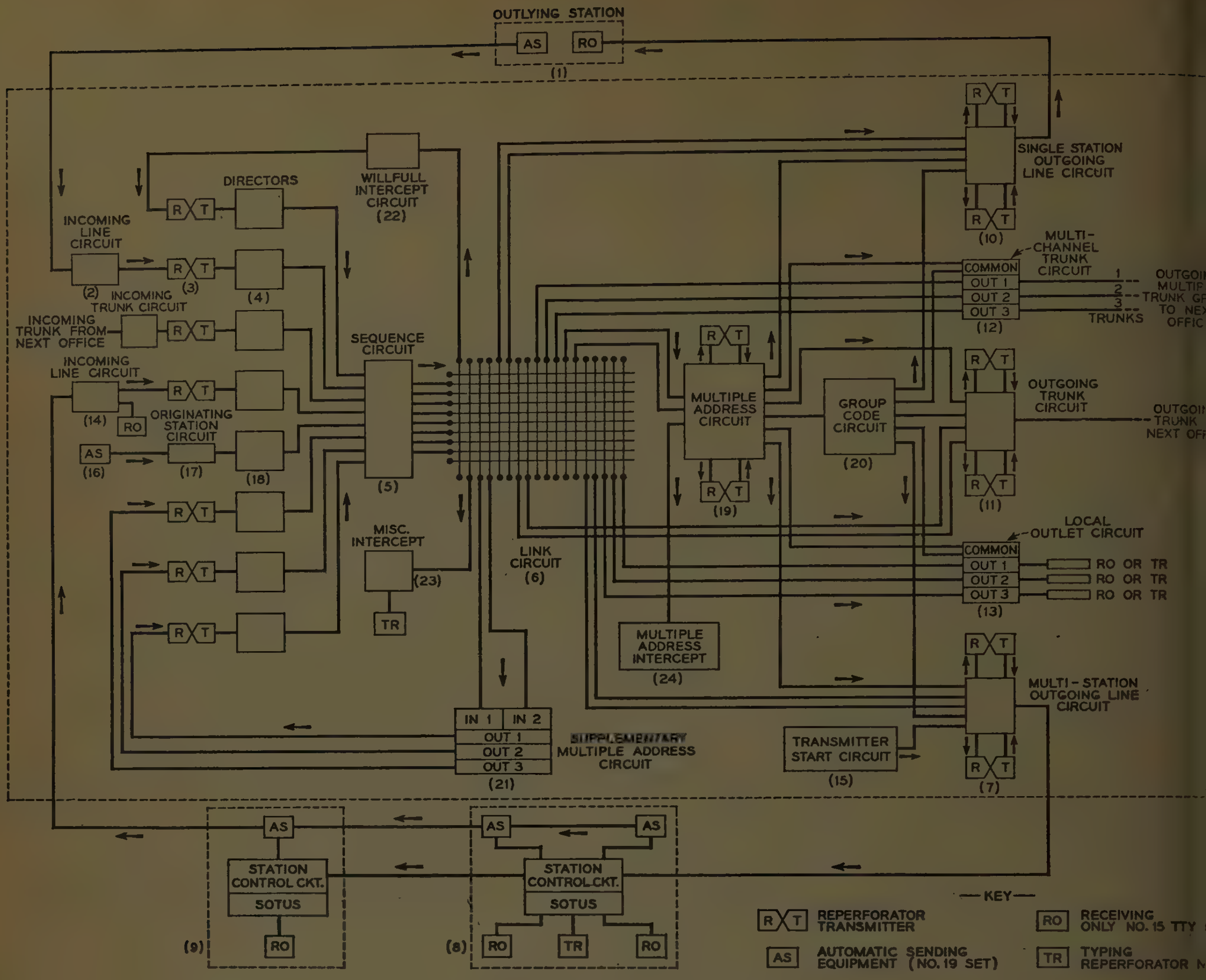


Figure 2. Block diagram of the 81C1 system

acters in the receiving side of a reperforator-transmitter brings into action an associated director circuit (4). The director circuit causes the reperforator-transmitter to read the first two characters which is the code of the station of destination. These two characters taken together are decoded by the director circuit to indicate the outlet of the switching office over which the desired station may be reached.

OUTGOING MULTISTATION LINES

It will first be assumed that the station of destination is located on a multistation line. A multistation line may have connected to it up to ten receiving stations. The outgoing line circuit (7) is equipped with two reperforator-transmitters on the receiving sides of which messages switched to this outlet are perforated for delivery to that line. The use of two machines in connection with an outgoing line materially cuts down the time this outlet will appear busy to incoming messages and also permits loading the line itself very close to its full capacity.

When the director determines that this outlet is the one on which the desired station is located, it tests the outgoing line circuit for the availability of the receiving side of one of its reperforator-transmitters.

If both machines are busy, the director circuit w maintaining its test until one of the machines beco idle. As soon as one of the machines becomes idle sending side of the reperforator-transmitter of the incon line is connected to the receiving side of the outgoing machine by means of the sequence circuit (5) and crossbar switches of the link circuit (6). The use of sequence circuit prevents more than one connection f being made through the crossbar switches during brief period while the connection is being established, simultaneous connections up to the capacity of the swit may exist at one time.

When connection is made from an incoming line cir to an outgoing line circuit, this connection being kn as a cross-office connection, the directing code and message is reperforated in the machine of the outgoing and when the director reads the "Figures," *H*, "Lett characters at the end of the message the cross-office nection is released.

The outgoing line circuit is arranged to deliver traffic perforated in its two machines to the line or alternate basis so that traffic delivered to one machine not receive preference in transmission over that in other. The stations, Figure 3, connected to a m on line are equipped with a station control circuit, ding a selector unit which is a motor-driven me- ical device for closing and locking a contact upon the ption of a number of characters received in a given ential order. For example, a station is coded on a aracter basis and to connect station (9) the characters nust be received in that order.

hen, therefore, the coding characters are sent to the by the outgoing line circuit, the proper station is ected and the "Carriage Return," "Line Feed" signals, h precede the text of the message, will deactivate the tor units so that they will not respond to 2-character binations in the message text that might connect other ons. The "Figures," *H*, "Letters" end characters will nnect the station and reactivate the selector units. A on control circuit may control up to three receivers (8).

OUTGOING CONNECTIONS

THE TRAFFIC to a receiving station is very heavy, the ame type of outgoing line circuit (10) is used, but the is equipped with only one receiving station, and this on (1) does not require a station control circuit.

he system is not limited to one switching office but have as many as desired. The number of switch- offices is determined by a proper balance between cost of switching equipment and the cost of lines. sages received at a switching office are delivered to her switching office over trunks. The single outgoing k circuit (11) is arranged to deliver its traffic over a k to another switching point.

he traffic between switching offices may be heavy gh so that one trunk does not provide adequate ca- ty. In this case a multichannel trunk circuit which may connected to it a minimum of two and maximum n trunks (12) is used. Reperforator-transmitters are used in this case as the trunks themselves provide the ired multiple switching paths. The speed of trans- ion over the trunk must be the same as the cross-office d, 75 words a minute. Connection from incoming to outgoing trunk is made on a first-idle-trunk basis.

LOCAL OUTLETS

ONDITIONS arise in some installations where large volumes of traffic for the same destination must be vered to points in the general locality of the switching e. The local outlet circuit is used for this purpose . These points may be equipped with ten receiving hines operating at cross-office speed directly from the ts without reperforator-transmitters on the outlet side. receivers are connected on a first-idle-receiver basis.

TRAFFIC FOR SWITCHING OFFICE

ME TRAFFIC received on incoming lines is destined for the switching office itself. The incoming line uits can be equipped with a receiving-only teletype- er in addition to the reperforator-transmitter (14). traffic then can be switched directly to the receiving- teletypewriter without burdening the switching hanism of the office, thus increasing its over-all effi- cy. Two specific codes are assigned for this use: a first character followed by *Z* which cuts on the receiving-only teletypewriter alone, or a first character followed by *H* which cuts on both the reperforator-transmitter and the receiving-only machine for reception of the message both at the switching office and some other station. When the volume of terminal traffic is not great enough to justify a receiving-only teletypewriter per incoming line, local outlet machines may be used.

SENDING FROM MULTISTATION LINES

IN THIS DISCUSSION traffic was introduced into the system from a line equipped with only one station. It will be noted that all lines are full duplex permitting transmission both to and from stations on a line simultaneously.

Multistation lines may be equipped with up to ten sending stations as well as the ten receiving stations heretofore mentioned. Inasmuch as only one sending station may send at a given time, sending is controlled by a transmitter-start circuit (15) which is associated with the outgoing line. Each transmitter on the line is assigned a single-character transmitter-start code which, when sent over the line preceded by a specific pattern, causes the transmitter, if there is tape in it, to start sending.

Upon termination of sending from any station on a multistation line, the transmitter-start circuit (15) takes control of the outgoing line circuit and stops outgoing transmission. This stoppage may take place any time while the text of a message is being sent or between outgoing messages. A pattern is then sent out ("Blank," a pause, "Space") which cuts off the receivers connected to the line without mutilating the copy being received and conditions the station control circuits to control their transmitters. The transmitter-start circuit then sends the start character for the transmitter next in sequence. If this next station has traffic, transmission will begin and the receivers that were cut off will be restored. If it has no traffic the next transmitter in sequence will be tried and so on until either traffic has been found at some station or all have been tested without finding traffic. In the latter case the circuit waits for a predetermined interval, chosen to suit requirements, before it again starts to test stations for traffic.

Figure 3 (left). Typical station on a multistation line

Figure 4 (right). Reperforator-transmitter

Each message in the tape at the sending station is terminated by "Figures," *H*, "Letters," which indicate the end of a message, but it may not be economical of line time to limit a transmission from a station to one message. The station operators are therefore instructed by the customer as to the maximum number of messages that may be included in a transmission. This number may be different for different stations depending on traffic needs. Following the "Figures," *H*, "Letters" characters of the last message two additional characters, *H* and "Letters," are perforated in the tape. These characters when registered in the incoming line circuit cause the transmitter-start circuit to test other sending stations on the line.

ORIGINATING STATION

FOR TRAFFIC originating at the switching office an automatic sending teletypewriter set is used (16) which is connected to an originating station circuit (17) and a director (18). The action of this director is the same as (4), except that it controls the sending set instead of a reperforator-transmitter.

MULTIPLE ADDRESS

TRAFFIC consisting of messages introduced at a sending point to be delivered to many receiving stations in the system is handled by the multiple-address circuit.

When a sending operator prepares a message for delivery to a number of stations, a 2-character multiple-address code is first perforated in the tape. The operator then follows this specific multiple-address code by the codes of the stations of destination. There is no limitation upon the number of station codes that may be inserted. The multiple-address code instructs the director at the switching office involved to deliver the message to one of two reperforator-transmitters associated with the multiple-address circuit (19). The whole message, addresses and text, is perforated in one machine of the multiple-address circuit.

The multiple-address circuit is equipped with a special type of director which discards the multiple-address code and then starts reading the individual codes.

To show the operation of the equipment it may be assumed that the first code is for a station on the outgoing line (7). When the reading of the address by the multiple-address director indicates that this particular outlet is required, a bid is made to the outlet. If one of the outgoing line machines is idle, it is connected to the multiple-address circuit.

Connection of the outgoing line circuit to the multiple-address circuit causes the multiple-address director to send the code to the connected machine of the outlet and then, without disconnecting from it, to blind the transmission path. The second address is then read and connection to another outlet made in the same manner. If another address is for an outlet already connected, the transmission path is unblinded, the new address transmitted, and the transmission path again blinded. In like manner, all the addresses are read and the required outlets connected by means of a multiple transmission path.

If an address calls for transmission to another switching office, a trunk is connected. In connecting to a trunk,
however, it is necessary to indicate to that trunk that t
is a multiple-address message, so that it can be handl
via the multiple-address message circuit in the next offi
When, therefore, connection is made to a trunk for the f
time, the multiple-address director inserts a multip
address code ahead of the first address.

When all the addresses have been read and sent to
various outlets, the "Carriage Return," "Line Fee
signals preceding the text are read. This causes all
connected outlets to be unblinded and the text of
message to be sent to all outlets simultaneously. T
"Figures," *H*, "Letters" characters following the mess
text release the connections.

GROUP CODE

PART OF the multiple-address traffic of many custom
includes many messages which are sent to the sa
group of stations as a matter of routine. Considera
saving in operating time and better accuracy is obtai
by assigning each of these groups a single 2-character co
When such a code is encountered by the multiple-addr
director a group code circuit (20) is called into action wh
makes a simultaneous bid to all the outlets concern
When all the outlets involved have been connected
multiple-address director sends the group code and
message to all these outlets.

SUPPLEMENTARY MULTIPLE ADDRESS

WHEN THE VOLUME of multiple-address traffic is lar
the capacity of the multiple-address circuit may
augmented by using the supplementary multiple-addr
circuit (21) which handles 2-, 3-, and 4-address messag

When using the supplementary multiple-address circ
specific multiple-address codes are assigned to 2-, 3-,
4-address messages, and the regular directors connect
incoming sources to one of a maximum of five input le
of this supplementary circuit. A maximum of ten c
puts, each equipped with a regular director and a rep
forator-transmitter, may be provided.

If an input level is called into action by the 2-addr
code, it is informed that two outputs are required. Wh
two outputs are connected, the first address is placed on
machine of the first and the second address on the mach
of the second. The text of the message then is transmit
to both machines and the connection released. Thus
2-address message has been broken into two single-add
messages which are handled by the directors connecte
the outputs in the same manner as does a director connec
to an incoming line.

Similarly the 3- and 4-address messages are reprodu
as three single- and four single-address messages.

INTERCEPTION

DIFFERENT opening and closing times of stations du
time zone differences or shutdown of stations
holidays or maintenance make it desirable to have a me
of intercepting messages bound for such a station or stat
for later delivery. Such a device, the willful interc
circuit (22) which may have one or two receiving pa
is provided for the interception of single-address messa

e operation of keys diverts the traffic to be intercepted this circuit. At a later time, this traffic which is stored a reperforator-transmitter can be re-entered into the tem automatically by means of its associated director.

Multiple-address messages which use individual station les are intercepted on typing reperforators by the ltiple-address intercept circuit (24).

Another type of interception is necessary to take care of assigned codes which may occur from errors on the part the operators or troubles in transmission.

When an unassigned or mutilated code is encountered either a regular or multiple-address director, a miscel-neous intercept circuit is called in (23), (24) which records addresses and text on a typing reperforator. Any ffic recorded in this circuit has its addresses corrected by switching office attendants and is re-entered into the tem at an originating station.

GUARDS AGAINST MESSAGE LOSS AND DELAY

MESSAGE NUMBERING METHODS, such as point-to-point and channel numbering, have been used on tele-ewriter systems for many years to discover system lures or troubles which have resulted in lost or delayed ssages. Messages are not considered lost if they are livered to a wrong point, as they can be rerouted. ither numbering method provides for quick discovery of loss or delay of a message, and in high-speed systems a ssage may be worthless if delayed more than a few nutes. Extra clerical work with its added opportunity human errors and the consumption of valuable line ne for number transmission are additional weaknesses number checking methods.

If proper precautions are taken to guard against message s and delay, the use of message numbering may be rtailed or entirely eliminated except as may be needed message identification. With this in mind the *81C1* tem was designed to include many safeguards against ssage loss as well as alarms to call the attention of oper-ng personnel to trouble conditions quickly.

The substitution of one valid code for another at the head a message by the operator will result in delivery to the ong station from which point it can be rerouted.

The appearance of an invalid code at the head of a ssage, because of operator error or failure of machines lines, when received at a switching office will direct the ssage to miscellaneous intercept with both an audible d visual alarm. If the invalid code appears on a ltistation outgoing line, provision can be made so that message will be typed on all receivers or on any master ceiver selected for this purpose. An audible and visual rm at the receivers then calls the operator's attention to message.

If no end-of-transmission combination is received at the itching office from a multistation incoming line, an tomatic end-of-transmission is registered after 45 seconds idle line time.

An open line or trunk to the switching office is both dibly and visually alarmed at the switching office. An en outgoing multistation line is visually alarmed at ch receiving station or at specific stations chosen for the purpose. Open single-station lines and loops to local outlets cause the receiving machine to run open.

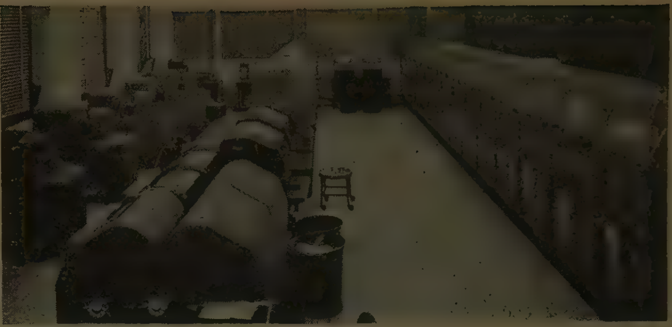


Figure 5. Switching office of the General Motors Corporation in Detroit, Mich.

The failure of an incoming line reperforator-transmitter or receiving-only machine to respond to signals, tape failing to feed through the punch blocks, torn tape, and low tape supply are all audibly and visually alarmed at the switching office. Similar conditions on other teletypewriter apparatus at the switching office not only are alarmed but the machines also are automatically made busy to further messages until the condition is cleared.

Failure of the switching circuits to complete their functions as well as certain other improper functioning of these circuits causes an alarm to sound.

MAINTENANCE OF SERVICE

ALL CIRCUITS and machines utilized in this system are wired through plug connectors in order to allow the immediate replacement of a defective circuit or machine by a spare. A system of keys and lamps is provided at a control board. At this board lamps indicate traffic flow and stations sending on all circuits, keys provide for controlling the traffic flow as desired, and other lamps identify alarm conditions in individual circuits so that the quick diagnosis of trouble is greatly facilitated.

Each office is equipped with a testing unit to which nearly all circuits can be patched for test and at which all machines can be tested and repaired.

EQUIPMENT ARRANGEMENTS

FIGURE 5 shows the switching office at the General Motors Corporation in Detroit, Mich. The machine cabinets, each of which mounts two reperforator-transmitters, are shown at the right and in the rear of the middle row. These cabinets are of the unit type which facilitate installation and additions. At the extreme right behind the reperforator-transmitter cabinets are the cabinets which house the relay circuits for the various functions that have been described. These relay cabinets are manufactured as packages containing such combinations of circuit units that great flexibility as to the initial size of systems, as well as their expansion or contraction after they have been installed, is obtained.

At the left of the office are shown the originating stations, while in the front center appear the terminal traffic receiving-only teletypewriters which are associated with the incoming lines and the typing reperforators associated with the miscellaneous intercepts.

Instrumentation for Analysis of Contact Wear

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THE INSTRUMENTATION presented here was developed to measure the magnitude of some of the factors affecting contact wear, so that the effects of these factors may be evaluated. The ultimate goal is to be able to use these instruments to determine the contact life of a specific design in a few hours, instead of the usual weeks or months required for the life-testing methods now used.

A review of some of the factors affecting contact wear is necessary to understand the purpose of the measurements which these instruments are designed to make. For example, the major factors for bridging-type double-break contacts for a-c control are included in an empirical formula which approximates the life of the contact tips:

$$\frac{M}{N} = I^2[C_1+C_2K^2t^2] \qquad (1)$$

where N is contact tip life; M is mass of contact material available for wear on the four contact tips; I is arc current during break; K is the ratio of the arc current during make to the arc current during break; t is milliseconds time duration of the arc during make; and C_1 and C_2 are constants. Some factors are implied in the constants, and some others were neglected, in deriving this equation.

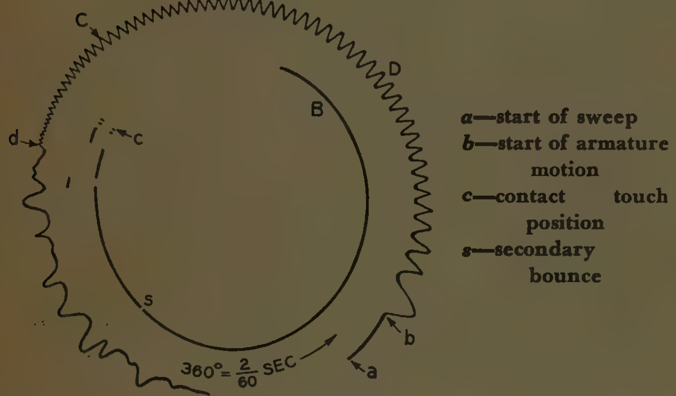

Figure 1. A-c contactor operating data. Trace *D* is time-displacement data for the magnet armature. Each cycle represents 0.00525-inch movement. Trace *B* is arc voltage representing contact bounce

A set of instruments has been developed to measure many of these variables. Basically, they consist of an oscilloscope and an arc time gauge. The arc time gauge measures total arcing time, t, in equation 1, during circuit make, and it may measure the d-c arcing time during circuit break. The polar-co-ordinate-type oscilloscope, together with its accessories, measures the following factors, one at a time: (1) The arc characteristic, as shown in Figure 1, trace *B*. (2) Instantaneous velocity of any moving part, as derived from complete time-displacemen data. See Figure 1, trace *D*. (3) Vibration and shoc characteristic and magnitude.

The oscilloscope measures arc characteristic by radi deflection of the spot in proportion to the voltage across th contacts, while the spot is sweeping circumferentially at given constant speed. In Figure 1, trace *B*, the spot moving counter-clockwise, with the direct 125-volt p tential on the open contacts, causing the spot to be d flected off the face of the tube. Then, at *C*, the conta closes, and the voltage drops to nearly zero, but, as boun occurs, an arc forms to give the spot a radial deflectio proportional to the arc voltage. These first bounces a called primary bounce, or that caused by the kinetic energ of the moving contact bridge. At *S* another bounce occur caused by transfer of kinetic energy of the magnet (moving parts other than the contact bridge) to the conta structure; this is called secondary bounce.

Instantaneous velocity is derived from a time-displac ment curve which is plotted from the data of the oscill gram in Figure 1, trace *D*. Each cycle on the oscillogra represents a movement of 0.00525 inch.

The time-displacement oscillograms are obtained attaching a lightweight film strip, having 190.4 paral lines per linear inch, to the moving part, and moving th film strip over a similar stationary strip. A light source one side of the film strips and a photoelectric tube on t other side result in one cycle of voltage output from t photoelectric tube amplifier circuit for each 0.00525-in movement of the film strip. This voltage is applied to t oscilloscope input to produce the oscillogram.

Vibration is measured by applying the output of standard vibration pickup to the input of the oscillosco to produce a pattern of vibration amplitude versus tim

No calibration of the oscilloscope is necessary wh making measurements of the arc characteristic or veloci The circular sweep is driven by a 3-speed (900, 1,8 3,600 rpm) synchronous motor. The spot then has uniform angular velocity of 900, 1,800, or 3,600 rpm, a time measurements are made by measuring the angle rotation.

The operation of the instruments is co-ordinated with t device under test so that data are automatically present on each operation of the test device. The operator is fr to observe and record data as desired.

While much work remains to be done before all of t factors affecting contact wear are defined and evaluat it is well established that contact bounce is a major fac to be considered.

Digest of paper 51-52, "Instrumentation for Analysis of Contact Wear," recommen by the AIEE Committee on Industrial Control and approved by the AIEE Techn Program Committee for presentation at the AIEE Winter General Meeting, Janu 22–26, 1951. Not scheduled for publication in AIEE *Transactions*.

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Lead-Alloy Power-Cable Sheath

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In a study of newly developed arsenical-lead alloys for sheathing of underground power cables, it has been found that these alloys are superior to copper-bearing alloys in the following aspects: withstanding bending caused by thermal expansion, resistance to creep caused by internal pressures, and life-to-fracture under tensile stress.

N 1939 it was stated in an AIEE paper[1] that "for many cables the expected e of present-day commer- l sheaths to cracking in nholes is only one-third to -thirds of the life of the ulation" and that "better ath materials are needed" obtain a "balanced cable ign." For over 20 years there has been an interest in the mmonwealth Edison Company in solving this problem.

The serviceability of cable insulations has been improved changes in materials and factory processes. Proof was ained[2] on the feasibility of operating the insulation at nperatures higher than those previously thought safe; l, for example, for various types of impregnated-paper- ulated lead-covered cables, permissible copper tempera- es have been established for emergency operation which from 10 to 30 degrees centigrade higher than those per- ted for normal operation.

Until recent years, the rules for maximum allowable erating temperatures generally were applied to emer- ncy loading when one line in a group feeding a given load s out of service. Since cable systems were built to avoid ceeding those limits, the normal loadings resulted usually temperatures much below the allowable limits. With establishment of emergency load ratings, the permissible ly normal loadings have increased considerably. (Ob- usly, this practice has resulted in sizable savings in plant estment costs for taking care of growing loads.)

With increased loads, the life of a given sheath to fracture creases much faster than the rate of increase in amperes.[2] major cause of the sheath breaks, which admit air and isture into the insulation, is fatigue cracking resulting m daily movement of the cable due to longitudinal ex- nsion and contraction with changes during the day in d on the lines. Such cracking occurs usually in the nholes where the cable movement causes slow bending, sometimes it occurs in the ducts. It is especially ublesome on the larger cables.

Another cause of trouble is the expansion of the sheath e to internal pressure. The sheath expansion may be ficient to impair the electrical strength of the insulation iously, or may continue until the sheath ruptures. In ner case, the result frequently has been either cable failure service or replacement of the faulty cable before failure.

In solid-type cable, the internal pressure is produced during the heavy-load hours by thermal expansion of the oil in the cable, especially in those high-voltage cables having oil reservoirs connected at the joints, or having hydrostatic head in riser cables or cables on slopes. In more recent years, cables with controlled continuous positive pressure on oil or gas in the cable have come into use. In order to withstand the internal pressure sufficiently throughout the life of the cable, the sheathing must have both good resistance to expansion (very low rate of creep) and good elongation to fracture (ductility).

Increasing the conductor temperatures causes increases in sheath temperatures and in daily ranges in temperature. The resistance of lead and lead-alloy sheaths to fatigue cracking and to expansion by creep due to internal pressure decreases rapidly with increases in sheath temperature.

In order to utilize the possibilities of higher loading, there arose, therefore, a need for a sheathing material which would withstand both the slow bending of small amplitude and the internal pressures much better than commercially pure lead sheaths, and which would have other suitable properties. So far, such material has been found in the arsenical-lead alloys of which several are now in use. One type, which was described in an AIEE paper,[3] consists mainly of about 0.15 per cent arsenic, 0.10 per cent tin, and 0.10 per cent bismuth in lead. Other types contain much less bismuth and about 0.04 per cent copper. Following is a presentation of the principal results of investigations and tests of the arsenical-lead alloys and their application to the operation of underground power cables. In this discussion, commercially pure lead includes common desilverized lead *A*, chemical lead, and lead containing added copper.

LIFE-TO-FRACTURE IN BENDING

A DUMMY MANHOLE simulating a full-sized manhole in the streets was constructed in the laboratory.[1] Cable samples with a joint in the middle were installed in the manhole and moved in 70-second cycles, simulating the movement which occurs in service. Most of the tests were made with 0.5-inch movement of the cable at the duct mouth at each end of the manhole, which is a typical daily movement on a well-loaded 500,000-circular-mil 3-conductor 12-kv line in Chicago. On such cable the average temperature of the sheath in the manholes is about 110 degrees Fahrenheit (43 degrees centigrade) and in the ducts is higher.

The results of such tests for various cables have shown

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ntial text of paper **51-68**, "Lead-Alloy Sheaths for Underground Power Cable," mmended by the AIEE Committee on Insulated Conductors and approved by the E Technical Program Committee for presentation at the AIEE Winter General ting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *sactions*, volume 70, 1951.

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Table I. Bend Tests to Fracture of the Sheath on 500,000-Circular-Mil 3-Conductor 12-Kv Cable in the Dummy Manhole

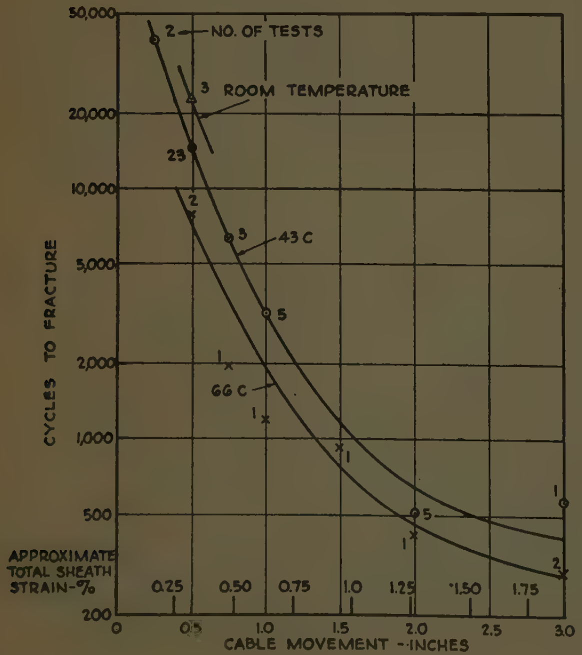
Temperature		Cycles to Fracture	
		Lead	Alloy
Room	Belted cable	11,420(2)	35,471(3)
Room	Shielded cable with metal binder	5,081(4)	17,943(1)
Room	Shielded cable with paper binder	9,720(12)	22,564(3)
43°C	Shielded cable with paper binder	2,755(2)	14,468(23)

Cable moved 0.5 inch at each end of manhole in 70-second cycles. The sheath thickness was 0.120 inch.
Figures in parentheses indicate number of tests.

that the number of cycles to fracture of arsenical-lead alloy sheaths is about three times that for lead sheaths under comparable conditions, and the ratio is sometimes greater. Data for one cable size are shown in Table I.

The type of construction of the cable exerts a considerable influence on the life-to-fracture of the sheath. If 3-conductor cable has a copper shielding tape over the insulation on each conductor and a copper or bronze tape with an intercalated-paper tape wrapped around all three insulated conductors to bind them together—the common construction of shielded cable—then the life-to-fracture of the lead sheath in bending is about half that of sheath on belted-type cable. The metal tape wrapped around the cable has some rigidity and tends to concentrate the working of the sheath over the edges of the metal tape. If the shielded cable has three or four paper tapes (total about 20 mils thick) instead of the metal and paper-tape binder, then the life of the sheath in bending is better, but is still less than that of the sheath on belted cable. However, the alloy sheath on the shielded cable with paper binder has been found to have over twice the life-to-fracture of the lead sheath on belted cable. The shielded-type of cable has some advantages in stability of the insulation under voltage and somewhat greater current-carrying capacity than belted cable with the same conductor size, and so there is a general trend toward use of the shielded type for cables rated above 8 kv. Some users specify paper-tape binders.

Figure 1 shows the results of bend tests of one cable design



with alloy sheath with various movements at each du
mouth. Most of the tests represented in these data we
made on 25-foot samples in the dummy manhole apparat
with an offset of 19 inches between the centers of the cab
in the duct and in the joint. Some of them were made
8-foot samples of cable bent into U shape, held at one en
and moved back and forth at the other end. With the m
tion adjusted to give the same maximum strain of the shea
in this test as in the dummy manhole, the resulting numb
of cycles to fracture of the sheath has been found to
about the same as in the dummy manhole apparatus.

These results indicate that at 43 degrees centigrade wi
0.32-per cent sheath strain (equivalent to 1/2-inch mov
ment of this cable at each end of the manhole), the avera
life-to-fracture at a speed of about one cycle per minute
about 14,000 cycles for arsenical-lead sheath. The 1/2-inc
movement corresponds to a daily range in conductor ten
perature of about 25 degrees centigrade on sections of th
cable longer than about 300 feet. These data relatin
movement to life-to-fracture of the sheath provide a mea
of predicting the service life of the sheath for various curre
loadings of the line.

In commercial operation the bending cycle is general
a 24-hour cycle. In order to obtain an indication of th
effect of slower movement than the 70-second cycles used
the dummy manhole on the number of cycles to produ
fracture of the sheath, bend tests were made on strips c
from cable sheaths,[4] with 1-minute, 10-minute, and 6
minute cycles. The number of test results obtained to da
is inadequate to establish definitely the relation betwee
speed of bending and number of cycles to fracture. How
ever, as is shown in Figure 2, extrapolation from the ava
able test results indicates that the number of 1-day cycles
produce fracture is roughly one-third of the number with
minute cycles. Since the action within the structure of th
metal is somewhat different in a strip of sheath when be
than it is in a sheath on a cable, the results of these te
can be applied in only an approximate manner to servi
conditions. The data indicate then that the life-to-fractu
of the alloy sheath on a well-loaded 12-kv line is about on
third of 14,000 cycles, or about 5,000 cycles. This corr
sponds to an indicated life-to-fracture of the sheath in th
manhole of about 16 years.

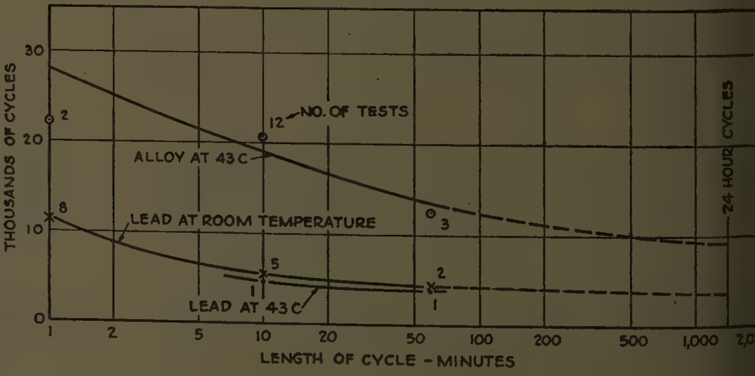
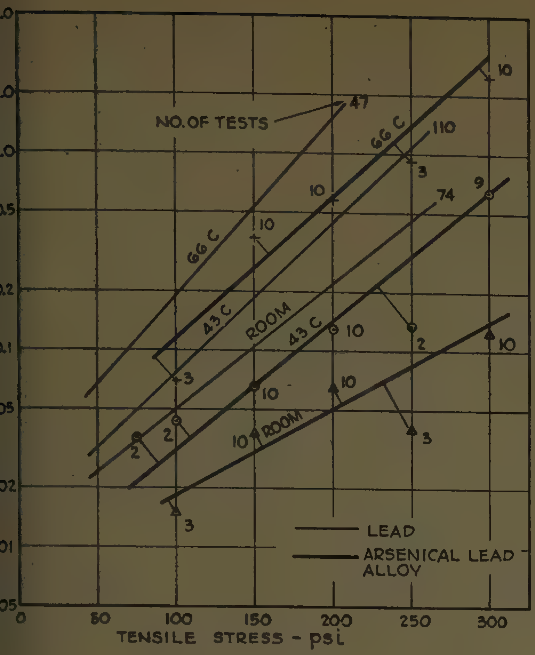


Figure 1 (left). Bend tests of 500,000-circular-mil 3-conductor 12-kv shielded cable with lead-alloy sheath

Figure 2 (above). Bend tests of strips at 0.3-per cent strain



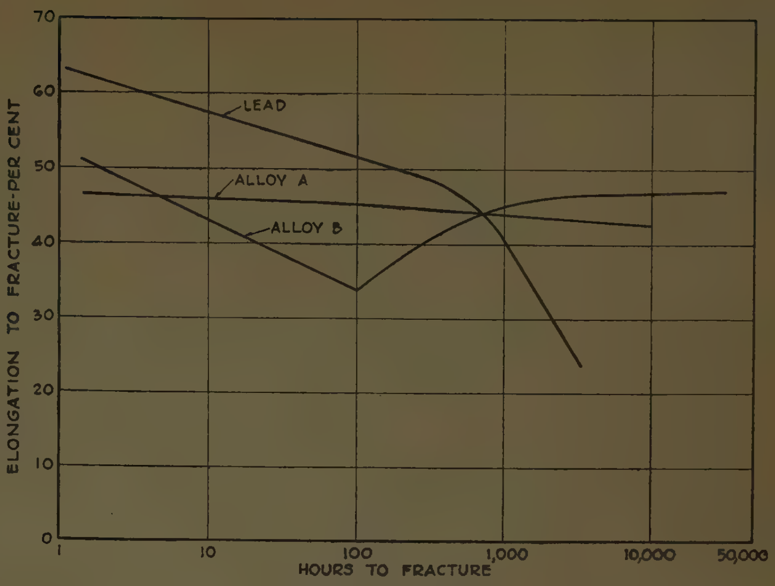


Figure 3 (left). **Creep rate of strips**

Figure 4 (above). **Typical trends in ductility at 43 degrees centigrade**

the line is not regularly well loaded, as is generally the , so that the average daily cable movement is only 1/4 , for example, then at the same temperature the sheath fracture in about 40,000 cycles in the laboratory test, or e than 40 years in commercial service. Furthermore, less load the sheath temperature in the manhole would omewhat less than 110 degrees Fahrenheit (43 degrees igrade) and the life-to-fracture would be even longer.

uring emergencies, the cable occasionally might be e heavily loaded for a day or two, with the result that cable movement might be as much as two inches at each of the manhole. If the cable is in a well-loaded duct k, the sheath temperature in the manhole may be about degrees Fahrenheit (66 degrees centigrade). For such ditions, the indicated life-to-fracture on test is only 500 es, and in service is, perhaps, one-third of that or 170 es. However, one or two load cycles under such condi- s would consume only about one per cent of the life of sheath, which is a negligible part of the service life.

hese bend tests have shown that the lead-alloy sheath a life-to-fracture at 1-inch cable movement about equal hat of lead sheath at 0.50-inch movement. Data have presented[2] relating cycles of movement to produce ure to daily range in temperature. Based on those , this increase in allowable movement corresponds to ncrease in daily temperature range of about 50 per cent. s, for equal sheath life, the alloy permits about 22 per higher current loading of the cable.

RESISTANCE TO CREEP

RSENICAL-LEAD ALLOYS are also markedly superior to lead in the ability to withstand stress, as indicated by of creep. The average results of a large number of of strip specimens under steady tensile stress[5] are n in Figure 3. The results shown for alloy lead were ined on the approved types. At temperatures be- n room temperature and 43 degrees centigrade, and at stresses which are most common for cable sheaths in service, the alloys take about 100 pounds per square inch higher stress than lead to produce a given rate of creep. At 66 degrees centigrade, the difference in stress is about 60 to 80 pounds per square inch. Thus, though the advantage of the alloy is not so great at unusually warm locations or during emergency operation, the difference is considerable.

These creep rates are based on the elongation of strip specimens under steady tensile stress between 1,000 and 2,000 hours of testing. Most of the tests on strips were run to 5,000 hours, but some were continued to as long as five years. Generally, after 2,000 hours the rate of creep under normal conditions of temperature and stress decreases slowly for a long period until finally a rising rate leading to failure develops. The decreasing trend occurs for both lead and the arsenical-lead alloys. Thus, the rates of creep shown in Figure 3 are a little higher than they would be for periods of years in service.

The strip specimens used in these creep tests were 1/4-inch wide in the gauge section. An investigation was deemed necessary to determine whether the results could be applied directly to the sheath on cable with internal pressure. Samples of sheathing six feet long with sealed ends were filled with oil and were maintained with internal pressure at room temperature for some samples and at 66 degrees centigrade for others. The rates of radial expansion of these sheaths over long periods of time (one test ran 13 years until the sheath split) were compared with the rates of elongation of the strip specimens of the same materials. In most cases, the rates of creep for long periods of time were practically the same for both the strip and cylindrical samples, but in some cases the rates for the latter were lower. The rates of creep shown in Figure 3 are, therefore, conservatively on the high side.

Good creep resistance is especially important for cables which are maintained with internal pressure. For oil-filled cable, the ability of the sheath to withstand higher internal pressures makes possible savings in the provisions of oil reservoirs for the thermal expansion of the oil. For gas-filled cable, higher pressures make feasible the use of higher operating voltage by raising the ionization voltage of the insulation. For the arsenical-lead-alloy sheath, a limiting hoop stress of 175 pounds per square inch has been established,[8] whereas the established limit for commercially pure lead sheath is 125 pounds per square inch.

Generally, the sheath in the duct is somewhat warmer than that in the manholes, and for a well-loaded line may average about 50 degrees centigrade. Based on these data, a lead sheath at 50 degrees centigrade and 125 pounds per square inch will expand by about 6.1 per cent in 40 years, while the alloy sheath at 175 pounds per square inch will expand by about 5.5 per cent. These figures are slightly lower than those indicated in Figure 3 to allow for the decrease in rates of creep which occurs with time. Thus, the established limit of 175 pounds per square inch for the arsenical-lead alloy is based on less ultimate expansion than is the limit of 125 pounds per square inch for lead. In the following section the alloy is shown to be much better able than lead to withstand such expansion.

LONG-TIME EFFECTS

COMMERCIALLY PURE LEAD does not harden with age. In fact, it will recrystallize quite readily under ordinary service conditions of temperature and stress. The tensile strength and hardness show little or no change with time, but elongation to fracture decreases in a very long time under stress.

Small amounts of some alloying substances can make lead an age-hardening metal so that the tensile strength increases and the ductility decreases over a period of several ye
This decrease might cause cracks to develop in ca
sheathing in normal handling during installation or ca
early failure due to cable movement in service. These
marks are in line with experience of ten years ago.

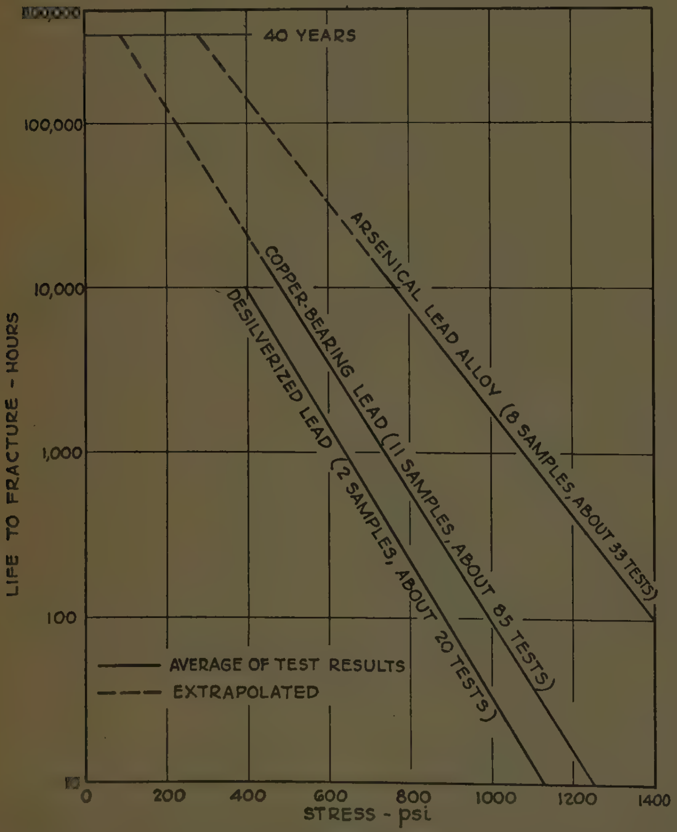


Figure 5. Life-to-fracture of strips under steady tensile stress at 43 degrees centigrade

The arsenical-lead alloys that have been accepted
commercial use are not age-hardening materials. Th
physical properties have been tested over a period of seve
years without showing any change in tensile strength
elongation. The hardness decreases in some cases.

In short-time tensile-strength tests, strip specimens
commercially pure lead sheathing fracture at about 2,
pounds per square inch with elongation of about 50 per c
to fracture in a 2-inch gauge length. Metallurgical st
shows that such fractures usually go through the grain
the metal. If the specimen is subjected to a steady ten
stress of, say, 500 pounds per square inch at 43 deg
centigrade, fracture might occur in a year with much
elongation. Metallurgical study shows that the cracks
such tests generally follow the boundaries around
grains. Thus, the nature of fracture of sheaths in ser
appears to be somewhat different from that in short-ti
tests, and depends more on the strength of the metal in
grain-boundary region.

Lead cable sheaths in service with internal pressure h
been found to burst open when the diameters have
creased by as little as 3$^1/_2$ or 4 per cent. These shea
were fairly uniform in thickness around the circumfere
Therefore, the dependable life of such sheathing can
considered to be ended when expansion of about t
amount is reached.

The arsenical-lead-alloy sheaths have been found to h
good ductility in long-time tests. Some typical test res
are shown in Figure 4. In some cases, such as alloy *A*,
elongation to fracture remains almost unchanged in test
over a year. In other cases, such as alloy *B*, there is a
cline in ductility at first and then for tests of longer durati
higher values are shown. It appears that over long peri
of time in service these alloys can be depended upon to
pand by at least 10 per cent before fracture occurs. Th
more than enough for most practical purposes. The abi
of the sheath to expand without bursting is of value
solid-type cable in which oil is fed to the cable from re
voirs connected to the joints or from terminals or for ca
installed vertically or on steep slopes where the hydrost
head of oil creates internal pressure at the bottom. It i
value, also, for pressure-type cables such as low-press
oil-filled cable and gas-filled cable.

Figure 5 shows the relation between stress and tim
fracture in tests of strip specimens at 43 degrees centigr
with steady tensile stress. In addition, a few tests
sheaths at stresses of 200 to 315 pounds per square i
some to fracture in as long as 13 years, have been made
cable samples with internal pressure, and the results h
been generally in line with the relations shown on
figure. These data show that to produce fracture in
hours, for example, the alloy sheath requires about
pounds per square inch greater stress than does cop
bearing lead sheath. The difference between alloy
lead decreases for longer tests at lower stresses. If t

are extrapolated to 40-year life, then the indication is the average stress to produce fracture of the alloy th is about 280 pounds per square inch, and that for per-bearing lead sheath is about 90 pounds per square . While such extrapolation is only approximate, the furnish definite evidence of the marked superiority of arsenical-lead alloy.

INSTALLATION OF CABLE

NCE arsenical-lead-alloy sheath is somewhat harder and stronger than lead sheath, it is somewhat better to resist scoring or abrasion when the cable is pulled the duct. This feature is especially of value for the e and heavy cables. Also, the higher tensile strength of alloy sheath is of some advantage in withstanding the es to pull the cable into the duct.

Slightly greater force is required to bend the cable to it into position in the manholes. However, alloy-thed cables with large conductors having over-all neters of 3.0, 3.3, and even 3.4 inches, have been in- ed in 4-inch ducts in 600- to 700-foot lengths without substantial difficulty. For cables smaller than 3.0 es, the difference in handling has not been noticeable.

a few cases, cracks have developed during installation me of the early alloy sheaths, mainly on cables having neters about 3.3 inches. Those sheaths were found to bnormally hard and low in ductility in the region of the tures. This condition was due to improper conditions xtrusion of the sheath at the factory. Investigations e shown that, in order to avoid such troubles and to in uniformly good properties of the alloy, close control he treatment of the metal, both in the lead press and r it leaves the lead press, is necessary. The methods control of the extrusion process have been improved.

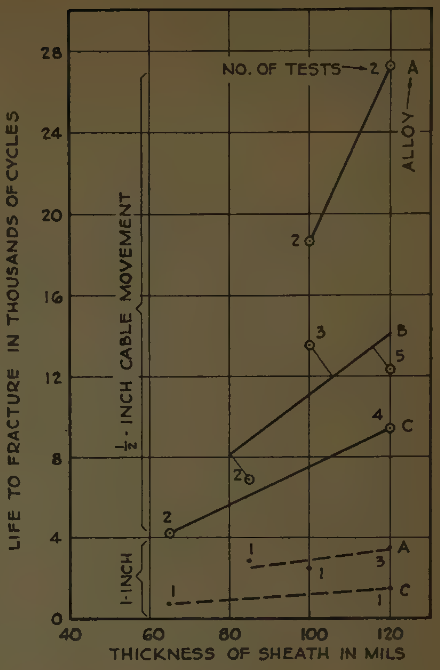
he lead alloy-sheath withstands vibration much better[3] does lead sheath. This is of interest for installation, icularly on bridges and on aerial messenger wire.

eginning in 1944, the Commonwealth Edison Company pted the arsenical-lead alloys for sheathing on 4- and 12- -conductor cables of the larger sizes (375,000 circular and larger) and on all 66- and 132-kv cables. Cable these alloys has been furnished by six manufacturers. e of the manufacturers are continuing their develop- t work on various lead-alloy sheaths. The tests de- bed here are also continuing.

POSSIBLE CHANGES IN CONSTRUCTION

NCE THE arsenical-lead alloy is considerably better than lead in the important characteristics for power- e sheathing, could not the change from lead to alloy th be accompanied by a reduction in sheath thickness a corresponding reduction in the cost of the cable? d tests were made on 12-kv cable having alloy sheaths 65 , 85 mils, and 100 mils thick in addition to the standard kness of 120 mils. The results indicated reduction in to-fracture equal to or slightly greater than the percent- reduction in thickness. See Figure 6. Where this erty is not the controlling factor in the service life of cable, the thickness might be reduced by about 10 per . With the corresponding reduction in life, the alloy sheath would still have an appreciable advantage in this respect compared with lead sheath.

Figure 6. Bend tests of 12-kv cable with alloy sheath of various thicknesses at 43 degrees centigrade



Some bend tests were made of cable with 85-mil alloy sheath and 75-mil fabric-reinforced neoprene jacket and of cable with 65-mil alloy sheath and 90-mil extruded polyethylene jacket. Difficulties were encountered in determining when the sheath under the jacket had cracked. However, according to the test indications, while the jacket is new and tight on the sheath, it is of benefit in lengthening the life-to-fracture if the repeated bending strains are large enough to produce appreciable wrinkling or buckling of the sheath of reduced thickness without jacket. With age in service, however, the jacket might loosen on the cable and become of little or no help to the sheath. The use of a jacket, of course, practically eliminates the possibility of scoring of the sheath during installation. Such scoring might reduce its thickness at places by as much as 15 per cent. Based on this consideration mainly, the commonly used specifications[6] for oil-filled cable were recently revised to permit a one-sixth reduction in sheath thickness when jackets are applied over the sheaths.

Alloy sheath as thin as 65 mils on cable of this size would be relatively weak to withstand the pulling forces involved in installing the cable. It would have a tendency to wrinkle when the cable was bent. It would require considerable care to make solder wipes on such thin sheath for joints and potheads. With the addition of a jacket over the sheath, it would make little or no saving in the factory cost of the cable compared to 120-mil alloy-lead sheath.

Some consideration has been given to the possible use of materials other than lead or lead alloy for power cable sheaths. While some of the synthetic materials which are now commercially available have very good resistance to moisture, none of them will keep out water completely as lead sheath does. Aluminum sheath would be lighter than lead sheath and could withstand higher internal pressures. The latter is of interest for high-pressure cables. For use underground, however, the necessary covering to prevent corrosion would make it cost more than lead-covered cable. Also, the high conductivity of high-purity aluminum would permit high circulating currents in the sheath.

SUMMARY

In order to carry safely the increased loads that correspond to the increases in temperatures that have been found feasible, particularly for the impregnated-paper insulation of underground power cables, a sheathing material better than commercially pure lead was needed to avoid considerable reductions in the life of the cable. Arsenical-lead alloys have been developed to meet this need. They are far superior to copper-bearing lead in ability to withstand repeated bending in manholes due to thermal expansion and contraction of the cable, in resistance to creep due to internal pressures, and in life-to-fracture under tensile stress. They are also somewhat better able to withstand the handling involved in installation of the cable. For some cables which operate continuously with internal pressure, arsenical-lead alloys permit use of a sheath without additional reinforcing covering.

The improved ability to withstand bending makes feasible the use of less offset in the manholes between center of the cable in the duct and in the joint. Thus, isting manholes can sometimes be used for the installat of an alloy-sheathed cable, where for the same cable hav a commercially-pure lead sheath enlargement of the m hole would be necessary to provide the necessary large sets. For new manholes, a reduction in offset permit reduction in the cost of the manhole. Development w on arsenical-lead alloys is continuing and some ca manufacturers are searching for other suitable lead alloy

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High Saturation Magnetic Alloy with a Rectangular Hysteresis Loop

J. F. LIBSCH EBERHARD BOTH

A study has been made of magnetic alloys which have a nearly rectangular hysteresis loop. This characteristic is desirable for materials used in saturable reactors, magnetic amplifiers, pulse transformers, and other nonlinear circuit elements.

THE PERFORMANCE of saturable reactors, magnetic amplifiers, pulse transformers, and other nonlinear circuit elements depends largely on the characteristics of the magnetic core material used. Generally speaking, for these applications the most desirable flux-versus-field-strength relationship is depicted by a rectangular hysteresis loop, preferably with a high saturation and a low coercive force value. Of the commercial magnetic materials, the grain-oriented 50-per cent nickel-iron alloys known as Deltamax, Hipernik V, Orthonik, and Permeron possess the most valuable combination of mechanical and magnetic properties required by nonlinear electrical components.

The saturation value of this material is about 15,000 gausses. This is relatively high and quite satisfactory for numerous applications. Still higher operating flux density values, however, dictated by the general tr towards reduction of and weight of electric equ ment, especially for milit field use. Therefore, authors and their associa have been studying the po bility of imparting rectangular hysteresis characteris to alloys containing 30- to 50-per cent cobalt and remainder iron, that is, those materials which have highest saturation values of all.

The rectangular hysteresis loop or, stated differen the almost complete flux reversal at a field strength clo equal to the coercive force, results from the proper al ment of the magnetic domains in such a way as to elimin all rotational magnetization processes. Processes kn to achieve this alignment under certain conditions mechanical stresses, grain orientation, and heat treatm in a magnetic field. The latter technique has been u exclusively in this study.

All specimens were prepared by powder metallu

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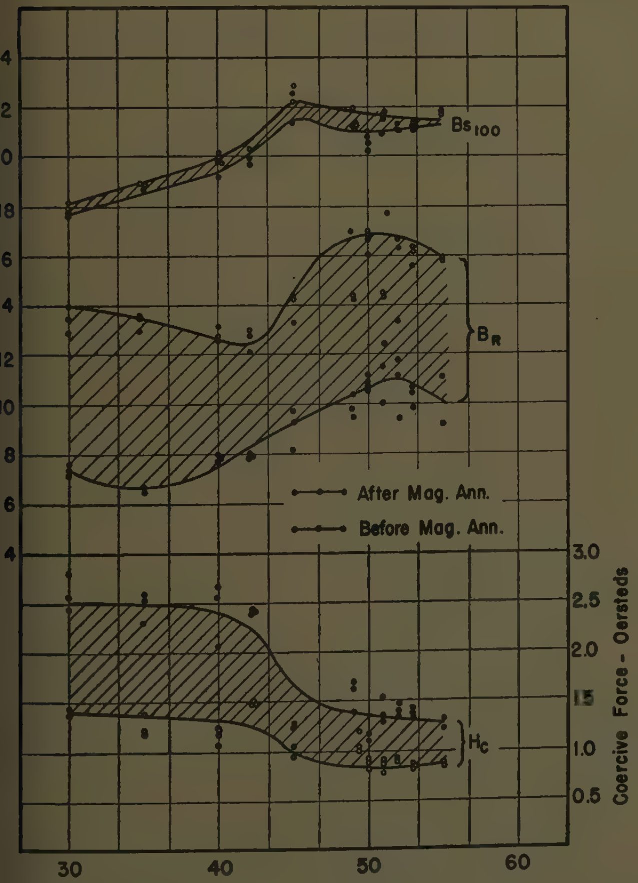
e I. Comparison of Cobalt-Iron and Nickel-Iron Rectangular Hysteresis Characteristics

	50% Co–50% Fe	50% Ni–50% Fe[2]
tion induction, B_s in gausses	22,400 (H=100)	15,000 (H=12.5)
ivity, B_r in gausses	19,000	14,500
ve force, H_c in oersteds	0.68	0.10
gularity, B_r/B_s in per cent	85	96.5

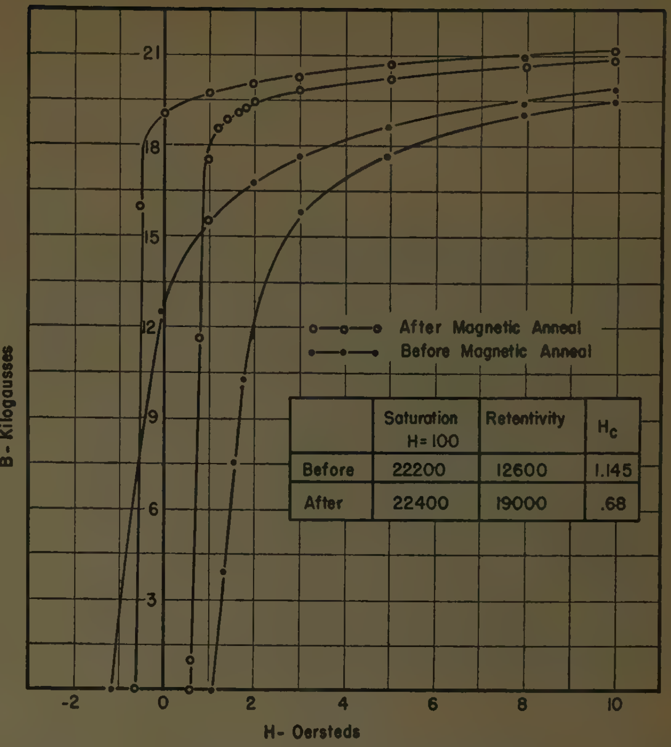
inally this method was chosen since it affords the ibility of excluding from the alloys to be studied such ents as manganese, silicon, or vanadium, which are g added to conventionally produced materials for ons of workability. A further advantage of the der metallurgy technique is its convenience in covering ther large number of compositions with a minimum unt of material and at low cost. It appears that merits could well be utilized in the production of lt-iron or other magnetic material in the form of ial finished parts.

fabricating the specimens, the elemental powders mixed, pressed to toroidal shape in a die, sintered at 0 degrees centigrade in pure dry hydrogen, and, wing a test of the magnetic properties in this state, ected to cooling in a magnetic field of 20 oersteds from mperature of 1,020 degrees centigrade.

igure 1 shows the saturation induction B_s, the re-ivity B_r, and the coercive force H_c of high-saturation lt-iron alloys containing 30 to 55 per cent of cobalt in both the sintered and the magnetically annealed condition. All alloys in this range are found to respond to the magnetic anneal by an increase of B_r and a decrease of H_c. A rather sharply limited optimum of this response occurs close to the 50-per cent cobalt–50-per cent iron composition.



re 1. **Effect of magnetic anneal on the magnetic properties of iron-cobalt alloys**



	Saturation H=100	Retentivity	H_c
Before	22200	12600	1.145
After	22400	19000	.68

Figure 2. D-c hysteresis loops and magnetic properties of 50-per cent iron–50-per cent cobalt alloy made from high-purity cobalt powder, before and after magnetic annealing

Figure 2 shows d-c hysteresis loops of the best sample of this composition obtained. Its properties also are compared with published values of the grain-oriented 50-per cent nickel-iron in Table I. With regard to rectangularity of the hysteresis loop as expressed by the B_r/B_s value, and with regard to the coercive force, the properties of the cobalt-iron alloy fall short of those of the nickel-iron alloy. It appears noteworthy, however, that its absolute retentivity value surpasses that of nickel-iron by more than 4,000 gausses.

Cobalt-iron alloys, especially those containing about 50-per cent iron and 50-per cent cobalt, respond to a magnetic annealing treatment by a marked change in the shape of their hysteresis loop. Although the B_r/B_s ratio and the coercive force of this alloy are inferior to the respective values of the grain-oriented 50-per cent nickel-iron alloy, the combination of higher absolute saturation and retentivity values may prove helpful for certain applications.

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Telephone Influence Factor in Synchronous Machine

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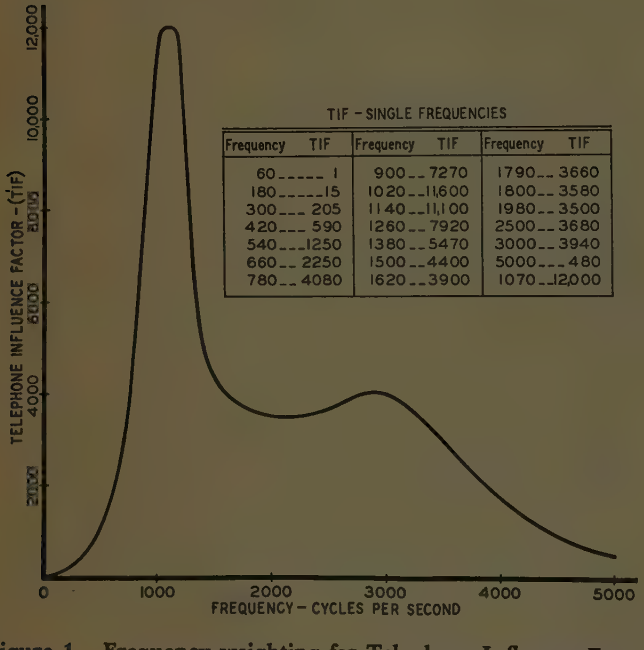
THE PRESENCE of harmonics in an a-c circuit, inductively coupled to a telephone system, may cause interference with the transmission of sound. As the result of a series of tests, a meter to measure Telephone Influence Factor (TIF), commonly called a TIF meter, was developed. The admittance characteristic of this meter, for various frequencies, is proportional to the values in the curve and tabulation in Figure 1. Quantitatively, TIF for any frequency, or combination of frequencies, is equal to the microamperes per volt input, as measured by this meter. TIF for 60 cycles is 1. As will be noticed from the curve, a frequency of 1,070 cycles has 12,000 times the interfering effect of a 60-cycle fundamental of the same amplitude. By use of a harmonic analyzer, the contribution of each component to the total TIF may be determined.

Harmonics in a-c power circuits usually result from characteristics of synchronous machines on that circuit. However, induction motors have also introduced appreciable interfering harmonics.

In designing synchronous machines, the following factors affect TIF: stator slotting; armature coil pitch; number of coils and turns per coil; angular span of phase belts; skew of stator slots, or rotor poles, or both; pole arc and shape; air gap and relation of slot width to slot pitch; and saturation in magnetic circuits.



TIF - SINGLE FREQUENCIES

Frequency	TIF	Frequency	TIF	Frequency	TIF
60	1	900	7270	1790	3660
180	15	1020	11,600	1800	3580
300	205	1140	11,100	1980	3500
420	590	1260	7920	2500	3680
540	1250	1380	5470	3000	3940
660	2250	1500	4400	5000	480
780	4080	1620	3900	1070	12,000

Figure 1. Frequency weighting for Telephone Influence Factor measurements

Stator slotting introduces harmonics which are equal to $2(S/P \pm 1)f$ where S/P is the slots per pole and f is the fundamental frequency.

Fractional slotting can be used to increase the value
S/P and thus the frequency of the resulting harmonics t
point where the interfering effect is greatly reduc
Chording can be used to reduce or eliminate certain h
monics. If the pitch of the stator coils is two-thirds of f
pitch, all odd triple harmonics are eliminated. Shape

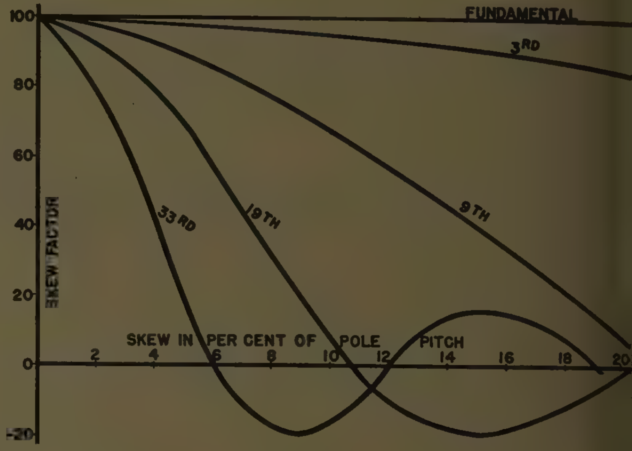


Figure 2. Skew factors for various skewings on fundament third, ninth, 19th, and 23rd harmonics

the pole face and ratio of the pole arc to pole pitch
important factors to be taken into account in eliminati
of harmonics.

Skewing either stator slots, or rotor poles, or a combi
tion of both may be used to reduce, or even elimina
specific harmonics. To eliminate any specific harmo
the amount of skew in inches must equal twice the p
pitch in inches divided by the order of the harmonic,
any multiple of this amount of skew may be used.
skewing exactly one slot pitch distance, all slot harmon
disappear. Figure 2 illustrates effect of skewing on vari
harmonic frequencies.

Increase in air gap will result in lesser flux pulsations a
lower TIF. Increase in saturation usually results in m
uniform flux distribution and lower TIF.

In general, TIF values will be much less under load th
on open circuit. However, the presence of capacitive lo
on a system may raise the TIF because of its low impeda
to high frequencies. A series of voltage transformati
will reduce amplitude of harmonics and thus reduce T
although highly saturated transformers may introdu
third harmonics into the system.

Digest of paper **51-124**, "Telephone Influence Factor in Synchronous Machin
recommended by the AIEE Committee on Rotating Machinery and approved by
AIEE Technical Program Committee for presentation at the AIEE Winter Gen
Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in A
Transactions, volume 70, 1951.

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echniques of Corona Loss Measurement and Analysis

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HIS ARTICLE discusses the test equipment which has been added to the test facilities of the 500-kv experi- ntal lines, the verification of the accuracy of the corona instrumentation, and the techniques of analysis and ıction of data which have been developed.

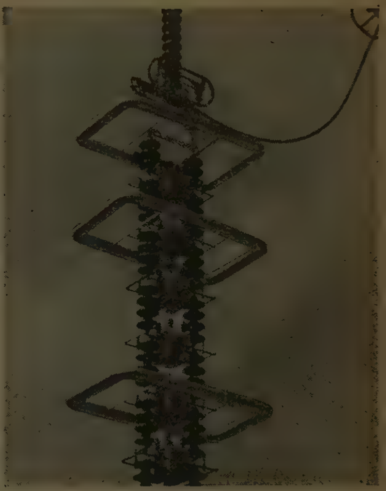
hree 3-phase lines, two 1.4 miles long and one 800 feet g, are energized by a 5,000-kva bank of three 500-kv le-phase transformers. The transformers were built as ventional power transformers using the form-fit tank n shell-form construction. The corona loss instrumen- on is mounted on top of the high-voltage bushings. vision is made for observing or recording the loss on n test conductor simultaneously. The instruments are d through a telescope mounted in an observation booth ch is about 50 feet away.

corona loss measuring circuit must operate at very low ver factors. It is therefore extremely sensitive to small se-angle errors which in more ordinary metering cir- s would go completely unnoticed. By way of compari- , an ordinary capacitor has a power factor of about 026, whereas a corona loss value of 0.5 kw per 3-phase e corresponds to a power factor of 0.00037 at 500 kv. ually, corona loss can be measured with an accuracy of 5 watts per phase per mile using the most sensitive tmeter scale.

orona loss is a much more variable phenomenon than is mmonly appreciated. Variations of ten to one under nsibly the same weather and conductor surface condi- s are not uncommon. In addition, corona is subject to h a "short-time aging" characteristic, which is a function he history of energization immediately preceding the lication of voltage, and a "long-time aging" characteris- which is the cumulative effect of energization over long iods. These factors make successive tests vary over a e range. Before these phenomena were fully recog- ed they were attributed to instability in the corona loss rumentation circuit.

rom early tests below the corona threshold voltage, when test lines, for all practical purposes, can be considered apacitor of zero power factor, the presence of a phase- le error in the wattmeter indications of about 18 minutes 0528 radian) was suspected. This angle was measured ependently by temporarily substituting a single-phase -voltage capacitor for one of the long-line test conduc- . This capacitor, Figure 1, was made up of Type-*3D* kva 7,960-volt capacitors connected in series, and its acitance was approximately equal to that of the test conductor. By comparing the readings of the wattmeters with the known losses of this capacitor, the phase-angle error was found to be constant. Therefore it could be corrected by placing a reactor in the voltage-coil circuit.

Figure 1. Top units of a high-voltage capacitor used for measuring phase-angle error



The principal source of this error was found to be the compact design and heavy shielding of the wattmeters, necessitated by the limited space available in the instrument cabinets.

A method of analysis was developed which permitted measurement of extremely small phase angles very accurately. This revealed a small variable phase-angle error which is a function of transformer tap position. This variation is caused by changes in the leakage flux in the transformer causing a change in the eddy and stray losses. The magnitude of this variation for all possible tap combinations has been determined, and corrections are applied.

A unique weather instrument, to record primarily fog and rain too light to be detected by a conventional rain gauge, has been developed. This consists of a movie camera which takes a weather picture every 20 minutes.

Provision is made to heat one of the test conductors artificially so that the effect of conductor temperature can be evaluated. A setup for recording the loss on a horizontal and on a vertical insulator string alternately for periods of 20 minutes each has been installed. A graphic voltage gradient meter for recording the voltage gradient at the earth's surface is available. A technique for converting data obtained with various test configurations and under different fair-weather conditions has been developed. This has been extended to give a method for converting single-phase data to 3-phase values.

Simultaneous records of corona-loss on nine different conductors, and of several weather parameters were taken. This information is correlated and reduced in several ways in order to make the data useful in the design of future extra-high-voltage transmission lines.

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t of paper **51-80**, "Techniques of Corona Loss Measurement and Analysis—Kv Test Project of the American Gas and Electric Company," recommended by AIEE Committee on Transmission and Distribution and approved by the AIEE nical Program Committee for presentation at the AIEE Winter General Meeting, York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transac-* volume 70, 1951.

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A Method of Gating for Parallel Computers

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IN ELECTRONIC digital computers information is stored in registers, which consist of a number of bistable circuits, usually called flip-flops. During the operation of the computer it frequently is necessary to transfer the information from one register to another. In parallel computers the information is transferred simultaneously from all flip-flops along parallel routes. The apparatus which causes the second, or slave register, to be set according to the first, or master register, is called a gate, and the operation is that of reading or gating the master into the slave.

Registers frequently contain as many as 40 flip-flops, and it is highly desirable that the gates be as simple and economical of equipment as possible. The gate described here is shown in Figure 1. It uses but two diodes per flip-flop, coupling the plates of each master to the grids of the corresponding slave. Two additional tubes are required to pulse the common plate supply of all the master flip-flops.

Normally, E_1 and E_2 have the value E, and the two registers are independent since both slave grids are at lower potentials than either master plate. When it is desired to set the slave to agree with the master, the voltage E_1 is lowered momentarily, thereby directly coupling the two flip-flops so that the state of the slave is determined by that of the master.

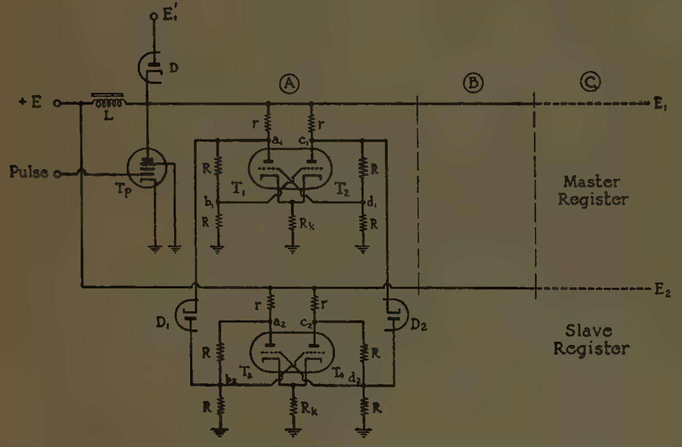

Figure 1. One flip-flop of each register showing the gating diodes and the common pulsing pentode

To understand the gating operation, consider a particular case in which the tubes T_1 and T_4 are conducting before E_1 is reduced. Then the point a_1 is lower in potential than c_1 and d_2 is lower than b_2. If E_1 decreases sufficiently the plate (a_1) potential of T_1 falls below the grid (b_2) potential of T_4, causing the diode D_1 to conduct and thus lowering the grid potential of T_4. This decreases the plate current of T_4, thereby increasing the grid (d_2) p tential and decreasing the cathode potential of T_3. these two changes are sufficient to cause T_3 to cond while the diode D_2 is still not conducting (a matter design), the slave flip-flop changes its state and agrees w the master.

If, on the other hand, T_3 had been the conducting tu originally, neither diode would have conducted and the fore no change of state would have occurred.

Further, if E_1 be reduced so far that both diodes condu the slave will, if necessary, reverse as E_1 falls and will be further disturbed as E_1 rises again if the resistors properly chosen.

By reconnecting the diodes the roles of master and sla are interchanged, and by using two pairs of diodes operation becomes bilateral; either register may be re into the other.

Furthermore, it is possible to use one set of diodes couple the master flip-flops to slave flip-flops remov any number of places to right or left. The other set diodes then can be used to return the information shifted to the master registers, and the apparatus becom a simple, fast, shifting mechanism.

The time required to transfer a number depends up the time it takes to reduce E_1 sufficiently. By pulsing very hard and limiting its minimum value by a support diode D, the whole operation can be made to take c siderably less than one microsecond for a 48-digit regis The pulse magnitude and duration must be sufficient the gates to operate. The pulse shape is otherwise important.

Experiment confirmed the satisfactory behaviour pected of this circuit, even when the parameters w deliberately chosen near their limiting values.

There are several relationships among the paramet which must be satisfied if reliable operation is to be tained, but none of them is difficult to meet in designing circuit. The circuit described meets all basic requi ments of a satisfactory gate for parallel computers. It be made fast: speeds of one-half to one microsecond easily obtained. Little extra apparatus is required only diodes are used. The gating operation is done direct coupling, making the gating wave shape relativ unimportant.

The principle underlying this gate is applicable to ot types of computer circuits than that shown in Figure and has been so used, successfully, with a great sav in equipment.

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Power Supplies and Rectifiers for Electric Railways in Providence

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A study of the power supply to the United Electric Railways was initiated when new construction necessitated the relocation of rotary converters. The question of replacement with more modern equipment and feeder and trolley system losses was studied by the use of probability methods.

HE UNITED Electric Railways (UER) provide transportation over 500,000 people in vidence and adjacent es and towns in Rhode nd. The operation of the nsportation system which ludes both electrically- l gas-driven vehicles, has been described in an earlier per.[1] This article is concerned only with the power sup- to the electric vehicles. At the time of this study there re 12 trolley bus routes and five street-car lines using buses and 93 cars. Since then, the trolley cars have n replaced by trolley buses.

he overhead trolley system was supplied at 600 volts from five Narragansett Electric Company substations. ure 1 shows the geographical location of the trolley ders and the substations. Except for a 4-kv 60-cycle tifier installation at Elmwood, the others, Manchester eet, North Main Street, Fountain Street, and Olneyville, re equipped with rotary converters supplied at 11 kv l 25 cycles from the Manchester Street Steam Station.

hen an expansion program at this steam plant made necessary to remove the four 40-year-old rotary conters located there, the question of replacement with more dern 60-cycle equipment was considered in conjunction h a comprehensive study of the entire power supply.

n commencing the study, it was evident that the d-c nsmission losses on the UER feeder and trolley system uld be the controlling economic factor in determining at kind of 60-cycle system should replace the 25-cycle tem, if such replacement were thought justifiable.

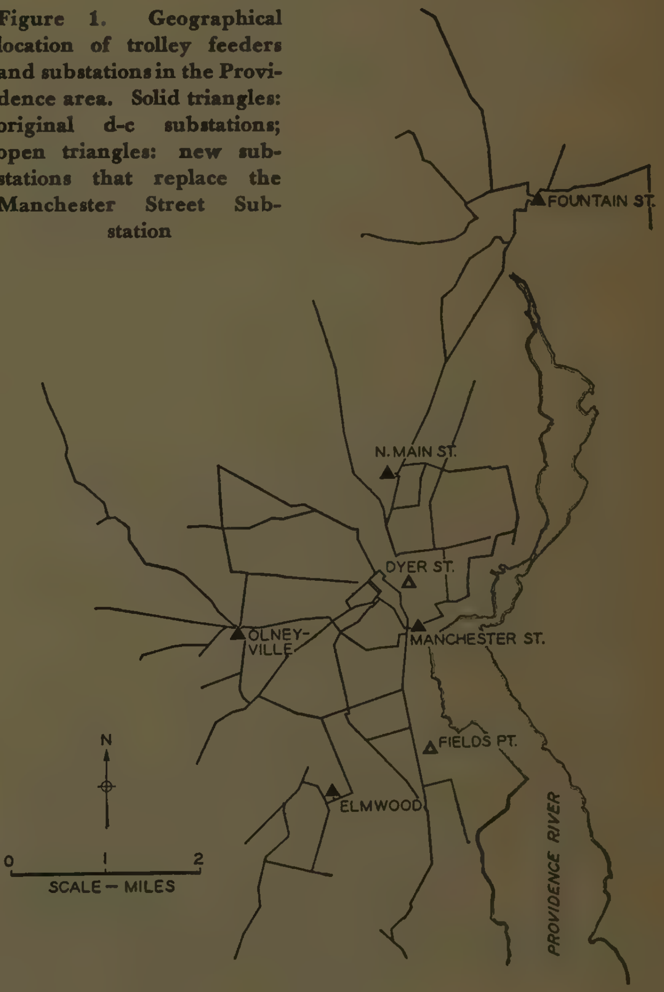
MEASUREMENT OF LOSSES

HE POWER INPUT to the UER system was obtained from the 25-cycle metering at the Manchester Street Station l the 60-cycle metering at the Elmwood rectifier. By raging the hourly requirements for the months of vember and December 1946, the requirements of an rage day were determined.

he net input to the d-c trolley system was obtained by tracting from this metered input the calculated 25-cycle nsmission and transformer losses and the calculated es in conversion equipment. Values of all line and machine loadings were taken from log sheet data.

The power consumption of the trolley buses was determined from a test thus equipped with an ammeter, voltmeter, and watt-hour meter. During November and December 1946, this test bus was assigned to each scheduled route for one day, except Saturdays, Sundays, and holidays. The meters were read at each terminal of the route as well as at the dividing line between the congested downtown area and the suburban area of the city. The ammeter and voltmeter were read before and during starting. A note was made of the number of passengers, relative traffic conditions, whether the bus heaters were on or off, and the time of reading.

Figure 1. Geographical location of trolley feeders and substations in the Providence area. Solid triangles: original d-c substations; open triangles: new substations that replace the Manchester Street Substation



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ntial text of paper **51-185**, "Power Supply Study and New Rectifier Installation for United Electric Railways of Providence," recommended by the AIEE Committee and Transportation and approved by the AIEE Technical Program Committee resentation at the AIEE Summer General Meeting, Toronto, Canada, June 25–29, . Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The power use by all the buses on one route was determined by multiplying the test vehicle consumption for each minute of the day by the total number of vehicles scheduled on that line. A minute-by-minute summation gave the hourly power requirements of that route. A minor adjustment was introduced at this point to include the effect of a slight difference in power consumption of two different types of buses. A similar method of calculation was used for the trolley-car routes.

The test vehicle power measurements were made over a period of two months; to correct these measurements to an average day it seemed reasonable to assume that all variations due to weather, traffic, passengers, and bus heaters would be reflected in the a-c input to the system. The hourly test values were multiplied, therefore, by the ratio of the input for the average day to the input for the test day for each hour.

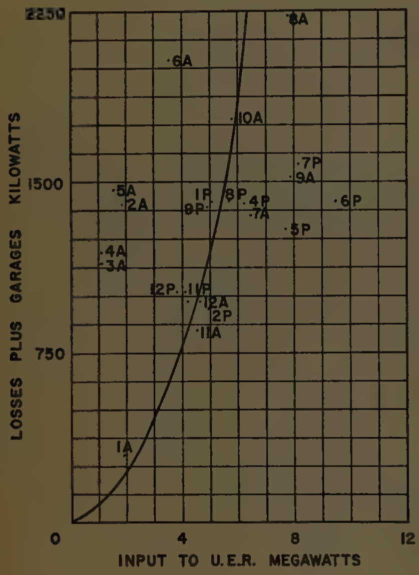

Figure 2. Trolley system losses plus garage use versus d-c input to the system

It was observed that the power requirement of the transportation system varied with the average daily temperature. During the months of November and December the weekday power use for 24 hours exclusive of Saturdays and holidays was 128,600 kilowatt hours for an average day for this period having an average daily temperature of 45 degrees Fahrenheit. Between the range of 30 and 60 degrees the power-temperature relationship was almost a linear function; the power use varied 2,000 kilowatt hours per degree change in the average daily temperature, increasing with decrease of temperature.

LOSS DETERMINATION FROM MEASUREMENTS

THE LOSSES on the d-c system as determined from measurements were obtained by subtracting the total power use of the trolley buses and cars from the net d-c power input to the trolley system at the UER substations. This calculation was made for each hour of an average day. These losses, which also included some unmetered use of power at the garages, were plotted against the d-c input to the UER and beside each point was marked the corresponding time. The plot is shown in Figure 2.

Most of the points fell reasonably close to a square-la curve, Figure 2. There were two groups that did nc (1) the values corresponding to the early morning hou between 2:00 and 6:00 a.m., and (2) the values corr sponding to the rush-hour periods of 7:00 and 9:00 a.n 5:00, 6:00, and 7:00 p.m. It was inferred that duri the early morning hours most of the input was used at t garages since vehicles on the road could account for or a small part of the total use. The wide divergence of t losses at other hours of the day was the subject of prolong study. Attempts to correlate the losses with the numb of passengers carried, the bus heating use, and gener traffic conditions were not conclusive.

To explain the lower losses during the rush hou it was noted at these times the buses were concentrat in the downtown area, and because they were closer to t supply points and because of the better diversity betwe bus current takings, the feeder losses were not increas in proportion to the number of buses scheduled; furthe more, during the evening rush hours the average b consumption was less, which indicated more waiting tin Losses during the morning rush hours were high compar with the afternoon rush hour periods because in the mor ing the buses go to the ends of the line to start their sche ules, whereas in the evening the buses go downtown start their runs.

CALCULATION OF LOSSES

THE LOSSES in the d-c feeders and trolleys caused by t bus power use were determined for the maximu number of buses that would be operating during the pe hour. On a positive feeder map of the d-c supply syste the 5:30 p.m. positions of all scheduled vehicles we marked. This network was simplified to equivalent rad networks on which the identity of the bus location w retained. The maximum number of buses on any o radial feeder and trolley was 19. The loss in each secti of these radial networks was determined using the r current equivalent to the intermittent takings of t number of buses drawing power through each section of t resistance network.

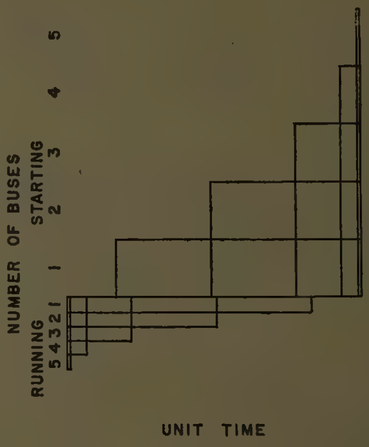

Figure 3. Relative durati and magnitude of curr due to simultaneous u of starting and runni power for example of t buses. Simultaneous sta ing or running of six more buses may be n lected. Unit time shown 127 seconds

A probability method was used to determine the durati of simultaneous use of power by buses on the same feed procedure was adopted from an article by H. A. r and K. W. Miller.[2] The calculations were based cycle that was assumed to average 10 seconds' drawing ing current, 10 seconds' drawing running current, and conds of no power use in each minute.

ese calculations were simplified by considering first the starting current. The results of a calculation of able duration of simultaneous use of starting current for an example of 10 buses on one feeder are shown he block steps in the upper part of Figure 3. In this simultaneous starting of more than five buses need be considered since simultaneous starting of six buses ld be expected to occur for one second out of each while that of seven buses would occur on the average ne second in each hour.

he operation of a bus on the starting, running, and stop tions are mutually exclusive events. Therefore, it was oned that if a bus were not taking starting current e would be a 4-to-1 chance that it would not be taking current; hence, the probability curve of the running ent requirements was assumed to be the inverse of the ing probability steps but of one-fourth the magnitude; as fitted into the block steps of the starting current laps as shown by the placement in the lower part of re 3. The maximum number of buses taking running ent would be expected to take place at a time when e would be none starting.

he rms current equivalent to the block steps of the ting and running current was calculated readily in s of the starting current of one bus. Similar calculas were made for other numbers of buses and the results erms of current factors k are shown in Figure 4. For given number of buses the equivalent rms current can obtained by reading the current factor value and tiplying by the starting current of a bus. For loss ulations a plot of k^2 was found to be convenient; when tiplied by the square of the bus starting current and resistance of a feeder section, the power loss was obed. The sum of the losses for positive feeder networks doubled to include the negative feeder losses.

he first calculations were based on a bus starting ent of 300 amperes as given by the maker. A comison of the calculated peak hour feeder losses with the sured value of the peak hour losses as obtained from er readings showed the calculated losses 45 per cent ı. In practice, because of voltage drop, the starting ent was observed to be between 200 and 250 amperes. calculated losses were made equal to the measured es by changing the assumed value of the bus starting ent from 300 amperes to 229 amperes. The 24-hour es on the average day were 18.15 times the losses on peak hour. An annual figure was arbitrarily assumed e 300 times the loss of the average day.

ALTERNATE METHODS OF SUPPLYING POWER

FTER DEVELOPING a method of calculating the losses in the d-c feeder and trolley systems and correlating calculated values with measured losses, it was possible use this method to evaluate the relative merit of any posed change in the power supply.

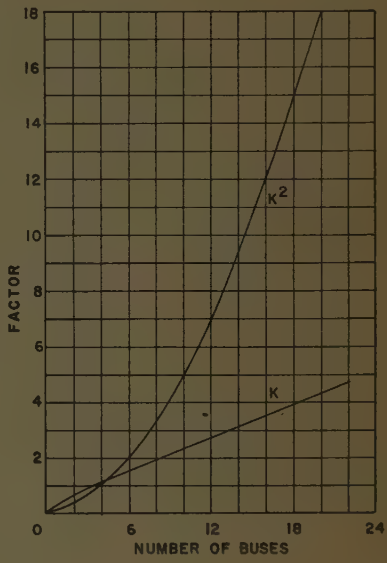

Figure 4. Current factors versus number of buses for a day of 45 degrees average temperature. To obtain the rms current equivalent for the number of buses indicated by the abscissa, multiply corresponding k value by the starting current of one bus. For loss calculations, use k² value and square of starting current of one bus

Preliminary study indicated that replacement of the present 25-cycle system of rotary converters by some type of 60-cycle rectifier installation would offer the most promise. The possibility of using comparatively small rectifiers in numerous places around the trolley system, tapped to existing 60-cycle feeders at either 4 kv or 11 kv, was studied in considerable detail. The proposed plans were examined to insure against the creation of new problems such as undesirable voltage flicker or telephone interference as well as to see if the proposal were economically sound. Three types of 60-cycle rectifier installations were investigated:

1. Rectifiers 500 kw and smaller on the 4-kv feeders.
2. Special locations for rectifiers tapped on the 11-kv feeders.
3. Large rectifier units in existing substations.

SMALL RECTIFIERS ON 4-KV FEEDERS

THE LOCATION selected for the first study of small 60-cycle rectifiers was a high-loss radial d-c feeder that extends about $3^{1}/_{2}$ miles beyond the present supply point at Olneyville and has an average of ten buses scheduled during the rush hours. The load was idealized to the extent that a uniform distance between buses was assumed. Five methods of supplying power were considered for purposes of comparison of losses; namely, a 500-kw rectifier at the supply end, a single 500-kw rectifier at the middle, or smaller units of two 300-kw, or three 200-kw, or four 150-kw units so spaced as to divide the line in equal parts. The rectifier sizes selected were standard units whose total capacity came closest to satisfying the maximum demand anticipated. In all loss calculations the probability method was used. Rectifier conversion losses were assumed to be seven per cent of the load. The results of these calculations are shown in Table I.

A comparison of these schemes shows that the greatest loss savings would be realized by using the smallest size rectifiers. However, all of these plans involve a net cost

Table I. Cost of Use of Small Rectifiers

Number of Rectifiers	Annual D-C Losses, Kilowatt Hours	Cost of Rectifier Installation	Compared with Radial Supply	
			Capitalized Loss Saving	Net Cost Penalty
Radial Supply	429,500	$ 33,000*		
1 500-kw	321,000	73,000	$ 9,500	$ 30,500
2 300-kw	219,000	108,000	18,600	56,400
3 200-kw	175,500	140,000	22,300	84,700
4 150-kw	180,000	186,000	21,900	121,000

* Based on the cost of 500 kw of capacity in a substation having 3,000 kw of rectifiers, at 1947 prices.

penalty when compared with a system at the supply end of the feeder located at an existing substation.

The preceding paragraphs pointed out the uneconomical nature of numerous small rectifiers. The one with the least net cost penalty would be the single large unit in the middle. The voltage flicker and the inductive interference problems were studied only for installations of the 500-kw size as this has the lowest net penalty attached to the small rectifiers.

Voltage Flicker. To estimate voltage flicker that would be caused by trolley bus loads on the 4-kv distribution system, eight possible locations where rectifiers might logically be placed were examined. A 2-per cent flicker was considered just noticeable; three per cent was assumed objectionable if recurrent (as would be the case); loads of less than 1-second duration were neglected. These calculations showed that out of eight possible locations studied six would have been classified as objectionable and two would have been borderline cases.

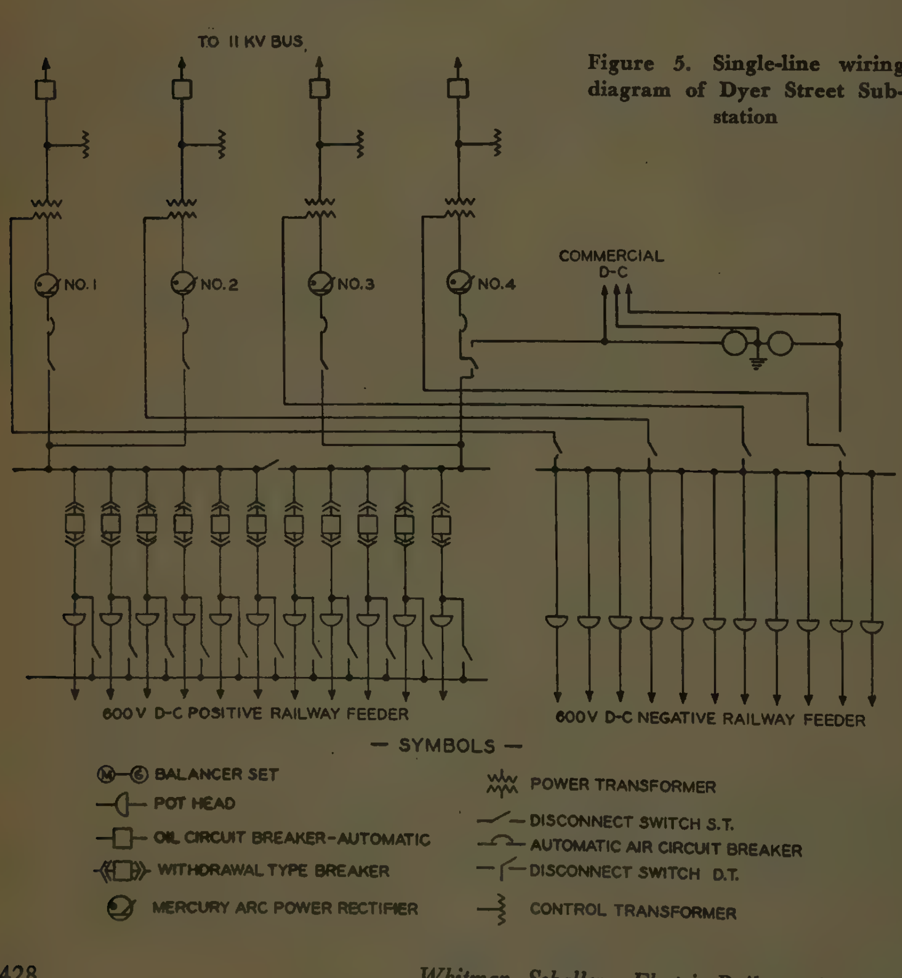

Figure 5. Single-line wiring diagram of Dyer Street Substation

Telephone Interference. A rectifier is inherently a proli harmonic generator. To determine the extent of t inductive interference problem with rectifiers on the 4- distribution system, reference was made to the AII Committee Report[3] describing a relatively simple analy that makes it possible to anticipate potential inducti interference problems in rectifier installations.

The three exposures most apt to cause interference a listed as: Exposure A, to parallel communication circu between the supply point and the rectifier, caused harmonic currents flowing in the supply feeder; Exposu B, to communication circuits that are parallel to extensio of the line that supplies the rectifier, caused by harmor voltages at the rectifier; Exposure C, to communicati circuits that parallel other a-c feeders radiating from t same substation that supplied the rectifier and caused harmonic voltages at the substation.

For the proposed installation of a 500-kw rectifier the 4-kv distribution feeder 9,000 feet from the Olneyvi Substation, it was determined that Exposure A betwee the rectifier and the supply would require further stud If the 4-kv distribution were an open-wire circuit with t neutral grounded only at the substation and if there we no unbalanced tapped loads in between, there wou probably not be any interference with the communicati circuits in cables; with open-wire communication circu there might be a problem. If the 4-kv distribution circu were multigrounded, the exposure would have been class as very likely to cause interference with open-wire con munication circuits; if paralleled by cable circuits it wou have been classified as indetern nate. The Exposure B on t feeder beyond the rectifier for th proposed location would ha caused trouble. The Exposure on the feeders which are radiatin from the supply station wou have offered no problem.

It was concluded that this a plication of a 500-kw 6-phase re tifier on a 4-kv distribution feed would cause interference on ope wire telephone lines having exp sures beyond the rectifier.

SPECIAL LOCATIONS FOR RECTIFIERS ON 11-KV FEEDER

THE PRECEDING ANALYSIS show that the application of sma rectifiers on the 4-kv system was n practical. The next logical st was to examine the possibility installing a single rectifier, tapp on an existing 11-kv industrial tie-line feeder, in an area where cor paratively large loss savings in t d-c feeders and trolley system mig be realized. A 750-kw rectifier w considered at the Sprague Stre Substation located about equid from Manchester Street, Olneyville, and Elmwood. e probability method was used to determine the ber of buses that could be supplied by this station, feeder changes were planned to take maximum ntage of the closer supply. This installation would resulted in an annual loss saving of approximately 00 kilowatt hours having a capitalized value of 00. The extra cost of this installation over the same int of capacity as part of a large rectifier substation stimated to be about twice this sum.

modified application of a rectifier supplied from an ng 11-kv 60-cycle feeder was the suggested use of a unit to supplement the power supply to an area e the d-c feeder losses were high. It was visualized a 300-kw rectifier could be made completely automatic installed in a sidewalk vault. By using a reactor in supply to obtain a drooping voltage characteristic, oading of the small unit would be prevented.

ch an installation might be located on the so-called ie Avenue feeder one-half mile west of the Manchester t Station. The calculations showed that the feeder would be approximately halved, thereby saving oximately 200,000 kilowatt hours of losses annually h would have a capitalized value of approximately 00. The estimated extra cost of such an installation the same amount of capacity, as part of a large ier substation, would be approximately twice the of losses saved.

ARGE RECTIFIERS AT PRESENT SUBSTATIONS

IE PROPOSED INSTALLATION of rectifiers on 11-kv eeders at special places, while not expected to cause lems of voltage flicker or telephone interference, d have a high net cost per kilowatt as compared with proportionate cost of the same capacity when con- ed as part of a larger rectifier installation at an existing ation.

survey of such possible locations for new rectifiers place the rotary converters at the Manchester Street on showed that Dyer Street and Fields Point would itable. Since both are closer to the load than the chester Street Station, an incidental loss saving of oximately 6,000 kilowatt hours per day and a 300-kw ction of the maximum 15-minute demand at the peak was expected. It was calculated that the minimum ge at the ends of trolleys during bus starting would be oved for practically all feeders in the southeastern on of the city.

er Street Substation serves the downtown area of the and is normally operated without 600-volt d-c ties to stations. As shown in Figure 5 there are ten railway rs leaving the station. The positive bus to which are connected contains a sectionalizing switch in the le which is normally operated closed and would be ed only in case of a bus fault or for maintenance work. feeders are arranged on the bus so that by closing de tie switches the entire area served by the station be carried from either half of the bus.

equipment is fully automatic. The positive feeder it breakers are equipped with rate-of-rise tripping and load-measuring reclosing control. The rectifiers have load-responsive sequencing control. Voltage-controlled light-load resistors are provided to limit the voltage rise during the early morning hours when only one or two buses are on the line, and there are regenerative braking resistors to absorb any energy pumped back by dynamic braking equipment on the buses. These resistors have a combination voltage and current control.

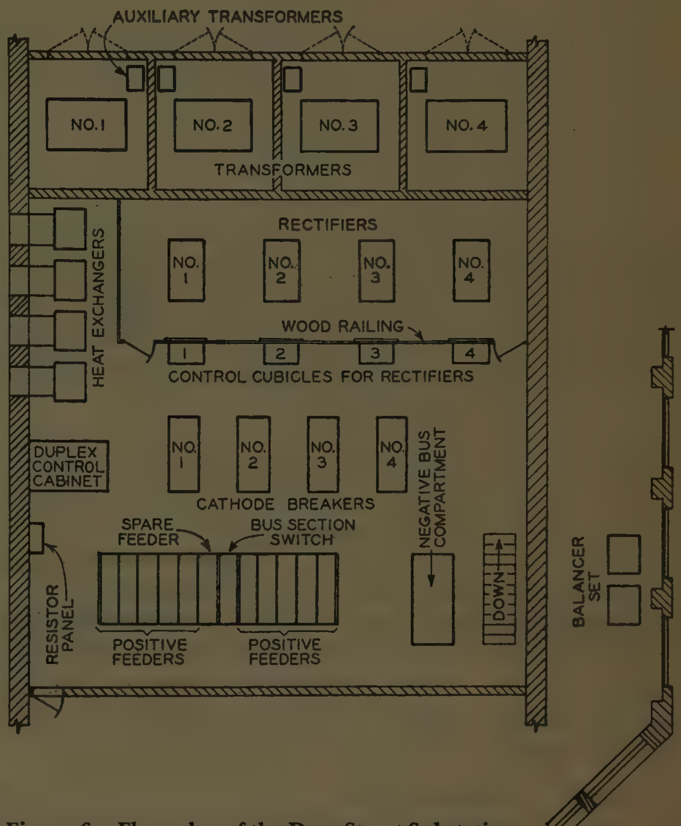

Figure 6. Floor plan of the Dyer Street Substation

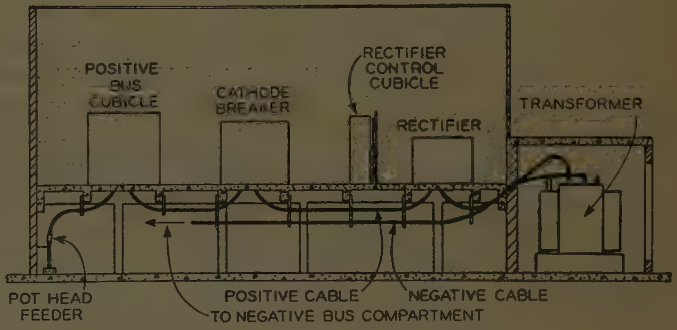

Figure 7. Typical section of the Dyer Street Substation

Figures 6 and 7 show a plan and section of the arrangement of equipment. This arrangement was designed to keep all power leads as short as possible with a minimum number of crossings. Since the building already existed, the freedom in spacing units was somewhat limited. Fortunately there was ample headroom to allow the construction of an elevated floor for all equipment except the transformers. This provided racking space for cables as well as providing the advantage of raising the equipment above possible flood damage.

RECTIFYING EQUIPMENT

The rectifier transformers, which are double-Y with an interphase winding, are 1,000-kw 6-tank ignitron type and are cooled with water-to-air heat exchangers.

The rectifiers are located within a fenced area which is entered only to make necessary checks, tests, or adjustments. In order to protect personnel all grounded metal has been kept out of the area and a space greater than an arm span separates the rectifiers. Hence, although the frame of a rectifier (which is at 600 volts positive potential) can be contacted, it is not possible to contact simultaneously the negative or grounded side of the circuit.

The floor of the area was given special treatment to avoid the possibility of shock. It is of concrete construction and all reinforcing and supporting steel was placed well below the surface. In addition, a 3/16-inch insulating layer of sand and bond mixture topped by 1/4-inch rubber tile was laid on the concrete. In laboratory test this bonding mixture and rubber tile gave a high-potential breakdown in excess of 4,000 volts, at 60 cycles rms, at the joint between tiles, and also had a high insulation resistance.

The rectifier auxiliary control equipment for the control of ignition, cooling water, and vacuum is mounted in a cabinet located four feet in front of each rectifier. Since this cabinet is grounded, a barrier sheet of insulation board was placed behind it to prevent anyone within the rectifier area from touching it. The first two feet of each control conduit leaving the rectifiers is made of insulating material and all control wiring has 1,000-volt insulation.

SWITCHGEAR

The positive bus structure is of metal-clad type with drawout circuit breakers. The choice of this type of equipment was largely dictated by availability, since delivery promises on other types did not meet the construction schedule. In order to protect the structure, a number of steps were taken against possible damage by arcing faults.

The rating of the four rectifiers together is 6,700 amperes continuous operation, 10,000 amperes for two hours, or 20,000 amperes for one minute. With normal currents of this magnitude at only 600 volts, a small amount of fault resistance will so limit the current in the event of an insulation failure or arc-over that overcurrent protective relays may fail to recognize the presence of trouble. On the other hand, a sustained arc of 1,000 amperes will soon cause serious damage. With an a-c system, differential relaying could be used to provide the required sensitivity, but on a d-c system this cannot be done readily. Hence, it was decided to install the switchgear structure on insulating maple sills and ground it only through a 20-ohm resistor. The maximum fault current at the bus structure thus was reduced to 30 amperes. In the event of a fault, a voltage-measuring relay connected across the grounding resistor is arranged to trip (after a time delay) all rectifiers supplying the bus and all feeder circuit breakers. The time delay is sufficient to allow fuses on control or instrument circuits to clear any miscellaneous wiring failu

In order to protect personnel who might be work around the bus structure at the time of a fault, the f surrounding it was treated the same as that around rectifiers and grounded metal was kept away from immediate vicinity.

One of the weakest spots in the insulation of a structure is the ammeters and their connections, wl really form an extension of the main bus work. Th have been cases on other systems where an amm insulation failure has started an arc which resulted serious damage. With fault current limited to 30 amp for a few seconds, this hazard is eliminated, but it felt that it would be desirable, if possible, to avoid remov the entire structure from service for such minor trou Hence, low-resistance 5-ampere fuses were installed in ammeter leads at the point where they leave the amm shunt. Although the fuses chosen were found to h quite uniform resistance, it was felt that some type adjustment should be available to maintain instrum calibration. This was accomplished by using shunts higher millivolt drop than the ammeters and instal adjustable calibrating resistors. In order to avoid clip resistance, fuses were obtained with bolted connecti

Another fusing problem arose in the protection of light load and regeneration braking resistors, which toge with their control devices are mounted on a wall pa These devices require 30- and 200-ampere fuses res tively and, since connection to them comes directly f the negative and positive buses, the fuses must be abl interrupt the maximum bus fault of 75,000 ampe Such fuses were not in production at the time but w under development; and laboratory models, which w later replaced with production units, were obtained f the manufacturer.

Each high-speed cathode circuit breaker with its disconnecting switch is mounted in front of the correspo ing rectifier in a steel frame which sits on insulating m sills. The frame then is grounded by a relay in par with a large red lamp which is mounted at the top of frame. If the circuit-breaker insulation should fail thus energize the frame, the relay would trip the rect 11-kv a-c supply and the cathode circuit breakers. If insulation failure is on the rectifier side of the circuit bre this operation will de-energize the frame. If the fai is on the bus side of the circuit breaker the frame remain energized until the bus side disconnect is ope In the meantime the red light will be lighted to warn the frame is alive. As a further safeguard to perso the frame and circuit breaker are totally enclosed on sides with doors made of insulating board. In the cas Number 4 rectifier, which may be connected either to 600-volt railway system with negative grounded or 250/500-volt 3-wire power system with neutral groun the calibration of the frame ground relay and the red l series resistor are automatically changed, when going f one system to the other, by means of auxiliary con on the positive selector disconnecting switch.

The negative bus structure was designed to con disconnect switching; at present, switches are insta for the four rectifiers; the outgoing feeders are tied ly to the bus. If, in the future, the trolley system ld be operated ungrounded, disconnect switches for negative side of each feeder would also be installed. structure frame was grounded solidly on the basis with the negative grounded as at present, no fault can r. If the system should be operated ungrounded, an ation fault in this structure would be serious only if were a simultaneous positive fault within the station. would be a very unlikely coincidence.

ontrol of the rectifiers is accomplished from the er control panel which contains the instruments, rol switches and relays, annunciators, and alarms for our rectifiers. The sequence in which the rectifiers ond to load changes can be varied to equalize the hours rvice between them, and, in addition, the selective pment is arranged to pass over any units which are ailable for service. This results in a total of some 240 ating setups which the relays must recognize. In tion, any unit may be taken out of the automatic ence and controlled manually. The load responsive rol is set to keep the equipment operating as near imum efficiency as possible, which is between half full load. Hence, an additional rectifier is brought operation when the load on the machines in service hes normal rating and a machine is dropped off when load per machine decreases to 40 per cent. The pment may be operated to shut down at night (after load has gone off) and start again in the morning, but since the Dyer Street area is normally isolated from the rest of the system, the control is set up to leave one unit on at all times. The annunciator system provides a record of abnormal operations that occur as well as initiating an alarm in the event that any unit is locked out.

The installation of the two 1,000-kw rectifiers at the Fields Point Substation was similar in general design features to the Dyer Street Station. The rectifiers are of the excitron type.

Both stations have now been in service a little over two years and, aside from initial shakedown troubles, operation has been satisfactory. The arc-back rate, so far, has been less than one per machine for the 2-year period, and interruptions due to other causes have been few.

When the stations were first put into service unexpected telephone interference was experienced; this was found to be due to capacitance coupling to ground through the capacitor-type lightning arresters used on the d-c feeders. The trouble was eliminated by the installation of an 0.007-inch gap in series with each lightning arrester.

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Two New Elements Confirmed by National Bureau of Standards

ecent spectroscopic investigations by the National au of Standards (NBS) give positive identification of two artificial elements. Not found in nature, the elements netium (Tc) and promethium (Pm) are by-products of ium fission; they were supplied by the Atomic Energy mission. Studies at the NBS of the first optical spectra ese elements have revealed many properties of the atoms their nuclei. They also have provided reliable wave- ths and intensity data for about 5,000 new spectral lines.

1949 the NBS received from the Oak Ridge National oratory several milligrams of each of these fission prod- for the purpose of making reliable descriptions and yses of the spectra characteristic of these artifical ele- ts. Four milligrams of highly pure Tc were used to ograph arc and spark emission spectra with a large dif- ion grating. The spectra were recorded several times 2,200 to 9,000 angstroms, and between these limits the elengths and relative intensities of about 2,300 radia- characteristic of Tc atoms and ions were determined. omparing intensities in arc and spark excitation, the could be assigned definitely either to neutral Tc atoms singly ionized atoms.

ve milligrams of Pm were made available for an inves- ion of the absorption and emission spectra. The rare-earth character of this sample was immediately disclosed by strong bands in its absorption spectrum and by an extremely complex emission spectrum when excited by electric arcs or sparks. The principal absorption bands were observed to have wavelengths of 494.5, 548.5, 568.0, 685.5, and 735.5 millimicrons. The arc and spark emission spectra of Pm were recorded photographically with a large diffraction grating, and the wavelengths and intensities of more than 2,200 lines were determined between the ultraviolet and the red.

Unfortunately, it was not possible with the sources employed to differentiate the spectral lines of neutral and of ionized Pm atoms, and the sample was too highly radioactive to recover for further experiments in the NBS laboratory. Consequently, the preliminary description of the emission spectrum of Pm, although it confirms the discovery of the long-sought rare earth and provides a sensitive test for future identification of Pm, is at present inadequate for structural analysis and derivation of atomic energy levels.

Although several different isotopes of both elements have been made artificially, they are all radioactive. The most stable identified isotope of Tc has an atomic mass of 99 and a half-life of about 500,000 years; and for Pm the corresponding quantities are 147 and 3.7 years.

Applications of a Mechanical Differential Analyzer to Electrical Engineering

EARL JANSSEN DON LEBELL

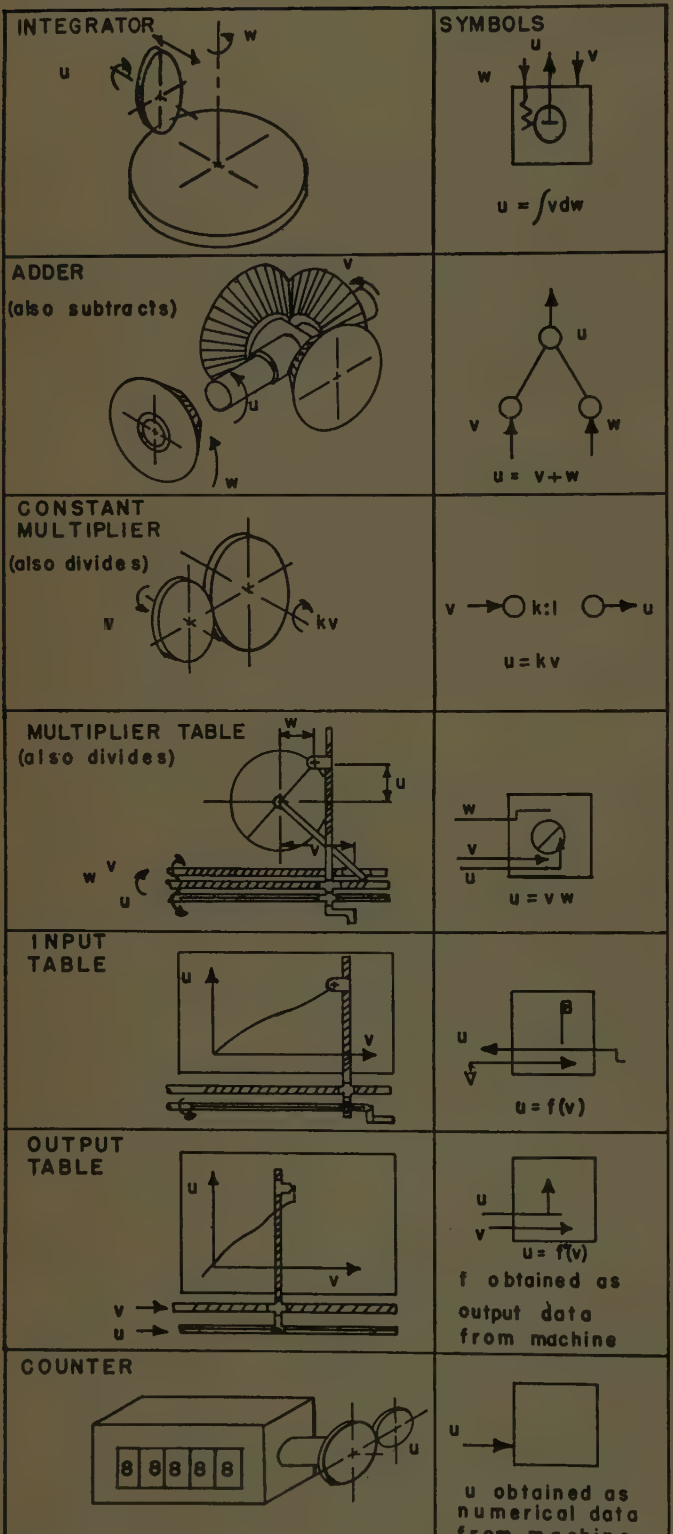

Figure 1(A). Basic components of a mechanical differential analyzer and their functions

The pertinence of the differential analyzer to the solution of certain types of electrical problems is explained by citing three examples. These examples have to do with magnetic amplifiers, pulse transformers, and particle (electron) accelerators.

THE PAST DECADE has produced an intensive
widespread series of developments in the comp
field. Many dollars and man-hours have gone
computer projects with such extensive results that it
been difficult for the practicing engineer to obtain comp
information on currently available computer facilities, t
capabilities, and limitations. At the same time it is bec
ing increasingly important for the research and design e
neer to have this information. He must be able to de
which computer, if any, should be employed to solve
particular problem. Too often, however, lack of in
mation, or misinformation as to the characteristics of t
devices, reduces the effectiveness of the engineer's eff
It is the purpose of this article to point out the applica
to electrical engineering of one such computer, the
chanical differential analyzer. Accordingly, there follo
description of this computer and its application to the s
tion of representative problems in electrical engineerin

DESCRIPTION

THE OPERATING PRINCIPLES of the analyzer will be
viewed briefly since the detailed features have
ready been treated adequately in the literature.[1-3]
differential analyzer solves differential equations by
struction within the machine of an analogue (model) o
equations to be studied. Quantities in the analogue co
spond to variables in the equations to be solved; h
quantitative information about the equations can be
tained from an examination of the analogue quanti
Variables of the mechanical differential analyzer are re
sented by angular displacements of shafts which are in
connected to the various basic components of the mach
These basic components perform the mathematical c
ations indicated in Figure 1*A*. The particular selection
arrangement of components is determined by the for
the equations to be solved.

The real power of the analyzer lies in the special auxi
operations and functions which can be produced as i
cated in Figure 1*B* and the convenient means for suppl

Earl Janssen and **Don Lebell** are with the Department of Engineering, Unive
California, Los Angeles, Calif.

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Research Project (Contract *W-28-099-ac-195*) of the University of California, spo
by the Air Material Command.

ary functions to the analogue (Input Table, Figure

hould be kept in mind that variables in the problem spond directly to angular positions (revolutions) of . When the shaft for any given quantity is turning in itive direction that quantity is represented as increas- nd, conversely, when the shaft is turning in a negative tion that quantity is represented as decreasing. The on of the problem proceeds as the independent vari- shaft turns. The applications to be described illus- these features.

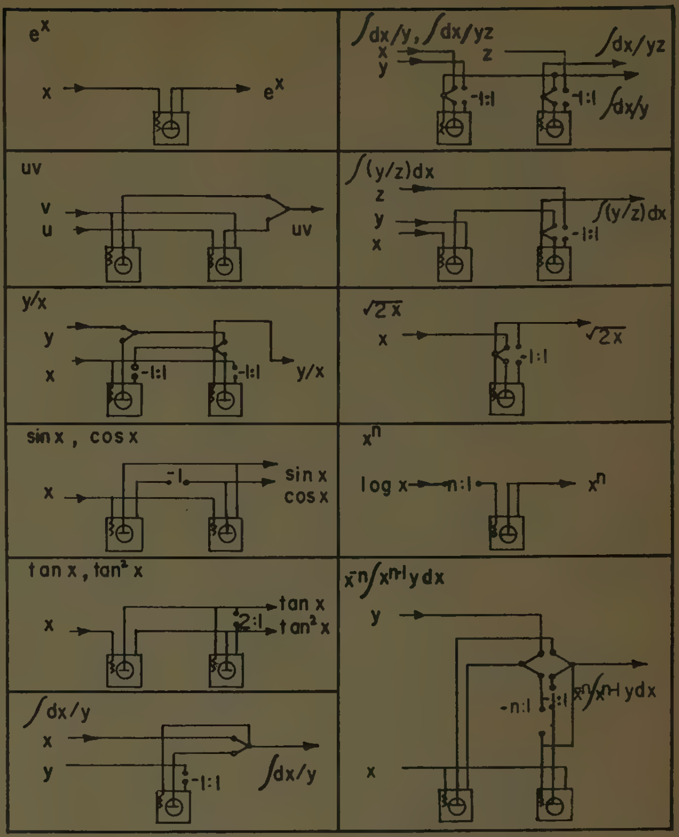


Figure 1(B). Representative auxiliary operations performed and special functions generated by a mechanical differential analyzer

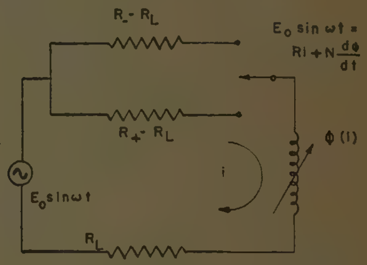


Figure 2. Equivalent circuit of a half-wave single-phase magnetic amplifier with self-feedback

MAGNETIC AMPLIFIER

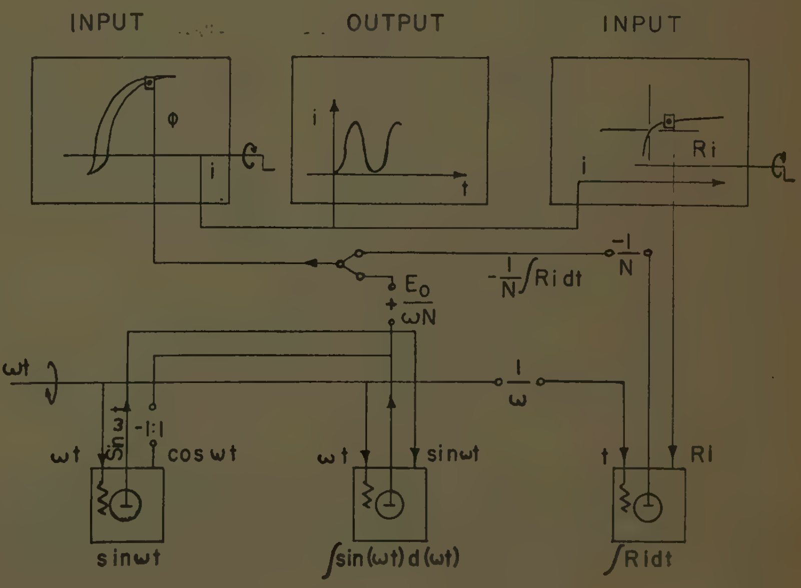
E SUBJECT of magnetic amplifiers[4] is one which has ecently received considerable attention. Briefly, a etic amplifier is a combination of specially designed ors, generators, and rectifiers which relies on effects of or saturation to produce amplification of power, volt- or current. A suitably designed reactor can be made oduce a large change in its effective impedance for a change in the current of a d-c control (saturating) ing.

equivalent circuit for a half-wave single-phase mag- amplifier with self-feedback appears in Figure 2.

hile it is a single-loop system whose loop voltage equa- s linear, two of the circuit constants (coefficients of the ential equation) are nonlinear. The rectifier exhibits constant resistance to current flow in the forward di- n and exhibits a high constant resistance to flow in the site direction. The inductance (or *B-H*) character- is nonlinear due to saturation effects, multiple-valued o hysteresis effects, and further, it is affected by the d-c magnetomotive force and the value of total peak-to- steady-state core ampere turns.

ese nonlinearities prohibit direct analytic solution. usual techniques for handling nonlinear coefficients are consuming or produce appreciable errors in the final ts. For these reasons it is highly desir- to employ the mechanical differential yzer for solution of problems of this type.

e equation obtained from the equiva- circuit (see Figure 2) is rewritten for ion on the differential analyzer as shown gure 3 with the schematic setup of the yzer for this equation. Actual solutions ined are shown as they are plotted on utput table. Note that actual dynamic resis loops characteristic of the mag- core material to be used, and voltage- nt characteristics of the rectifier ob- d from test can be used directly as input to the analyzer. Hence the usual sim- ng assumptions which frequently lead ohibitive errors are not needed to sim- or remove the nonlinearities.



$$\phi = \frac{E_0}{\omega N}\int \sin(\omega t)\,d(\omega t) - \frac{1}{N}\int Ri\,dt$$

Figure 3. Schematic diagram for solution of a magnetic amplifier problem

PULSE TRANSFORMER

ANOTHER APPLICATION of the mechani- cal differential analyzer, consider the of a pulse transformer.[5] Pulse transformers find wide application in coupling and impedance level changing for circuits handling short-duration (high-frequency) pulses (for instance, radar and digital computers). Their particular requirements and design call for a somewhat different analysis from that of transformers operating in the lower frequency ranges.

The equivalent circuit of a pulse transformer (Figure 4) was analyzed for a variety of circuit constant values in order to determine design criteria based on minimum requirements for the wave shape of the output pulse.

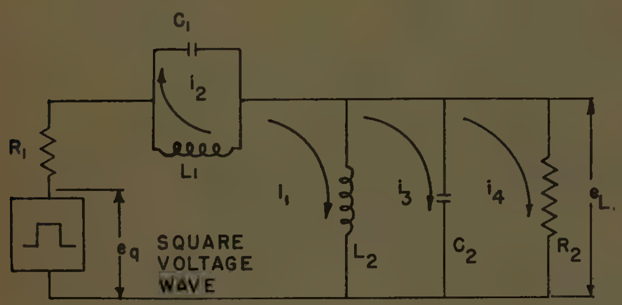


Figure 4. Equivalent circuit of a pulse transformer

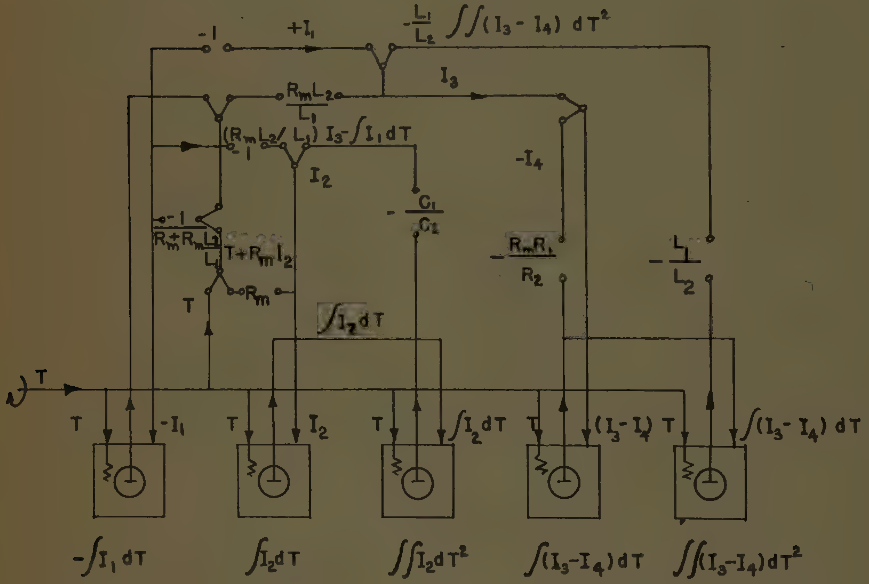


Figure 5. Schematic diagram for solution of equations 5, 6, 7, and 8

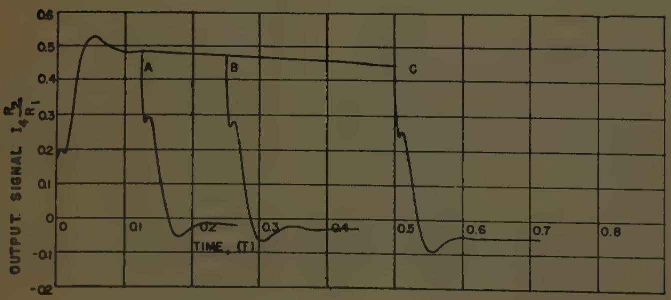


Figure 6. Representative transformer output signal wave shapes obtained from the differential analyzer. Output of pulse transformer for rectangular pulse input showing effect of varying pulse width

Simultaneous solution of the differential equations ari from the equivalent circuit can be achieved by fairly sta ard though tedious processes. In this particular analy study of the effects of changing the values of the circuit rameters was desired. This called for many solutions co sponding to several combinations of circuit consta Therefore, although a conventional analytic solution perfectly feasible for this problem, the differential anal was employed as a means of producing solutions in s mass-production fashion. Solution of this problem means of an electric analogue computer would have l even more rapid. However, accuracy considerations m the mechanical differential analyzer more suitable.

The equations describing the equivalent circuit, values of the combinations of circuit parameters, the mated ranges of all variables, the quantities to be plo and the initial conditions were obtained. (This in mation is required before any problem can be program on the differential analyzer.) The loop equations obta from the equivalent circuit (Figure 4)

$$e_q = R_1 i_1 + L_1\frac{d}{dt}(i_1 - i_2) + L_2\frac{d}{dt}(i_1 - i_3)$$

$$0 = L_1\frac{d}{dt}(i_2 - i_1) + \frac{1}{C_1}\int i_2 dt$$

$$0 = L_2\frac{d}{dt}(i_3 - i_1) + \frac{1}{C_2}\int (i_3 - i_4)dt$$

$$0 = \frac{1}{C_2}\int (i_4 - i_3)dt + R_2 i_4$$

are rewritten in dimensionless form increased generality of solution).

$$1 = I_1 + R_m\frac{d}{dT}(I_1 - I_2) + R_m\frac{L_2}{L_1}\frac{d}{dT}(I_1 - I_3)$$

$$0 = R_m\frac{C_2}{C_1}\int I_2 dT + R_m\frac{d}{dT}(I_2 - I_1)$$

$$0 = R_m\frac{L_2}{L_1}\frac{d}{dT}(I_3 - I_1) + R_m\int (I_3 - I_4)dT$$

$$0 = R_m\int (I_4 - I_3)dT + \frac{R_2}{R_1}I_4$$

where

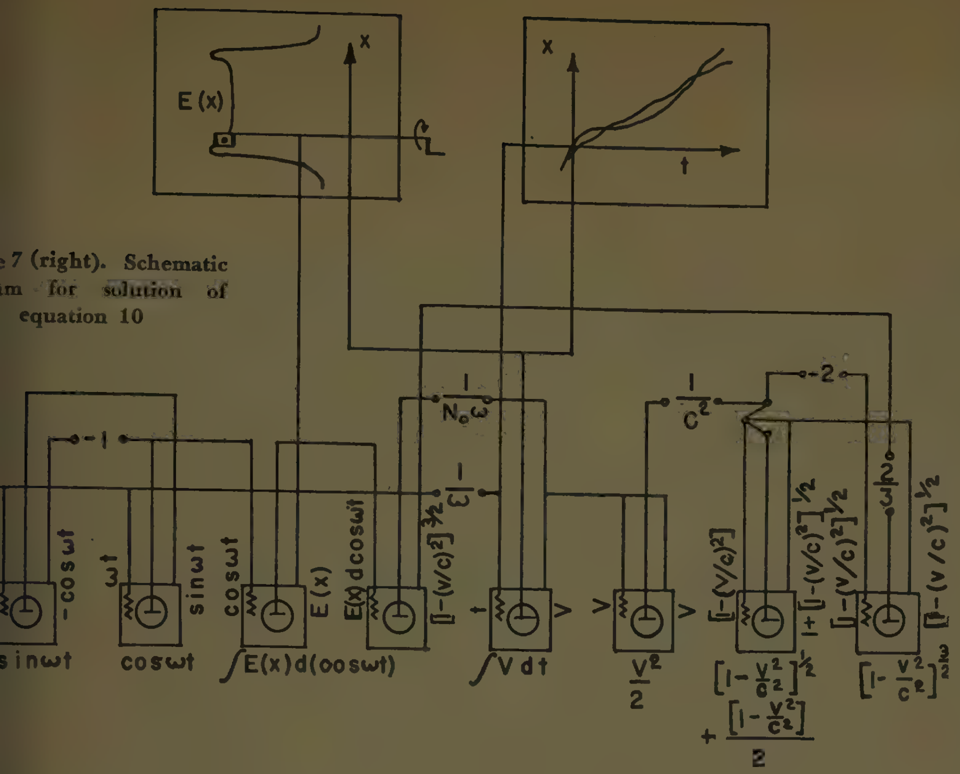
$$T \equiv \frac{t}{\sqrt{L_1 C_2}}$$

$$I_k \equiv i_k\frac{R_1}{e_{q(max)}};\ k = 1,2,3,4$$

$$R_m \equiv \frac{1}{R_1}\sqrt{\frac{L_1}{C_2}}$$

The schematic diagram from which the final mac diagram was constructed appears in Figure 5. Repr tative solutions (output curves) illustrating the effects o output pulse of certain circuit parameter variations shown in Figure 6.

It should be noted that the equivalent circuit (Figu is the result of several simplifying assumptions. The a transformer to be simulated by the equivalent circuit



7 (right). Schematic m for solution of equation 10

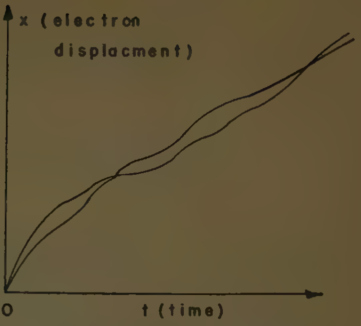


Figure 8 (above). Electron trajectories as obtained from the differential analyzer

ade to behave more nearly as the actual transformer by:

Considering the load resistance R_2 to vary as the l load (perhaps a magnetron).

Employing the actual nonlinear characteristics of L_2 core saturation data.

Increasing the number of loops, thereby simulating nearly the distributed parameter characteristics of the l transformer.

these refinements could be made without adding ap-able complexity to the solution of the problem as ob-d on the differential analyzer. However, these refine-s would create considerable difficulty in achieving a actory solution by other methods.

PARTICLE TRAJECTORIES

E DESIGN of electron tubes, particle accelerators, and ther devices utilizing the flow of particles under the nce of force fields often requires information about the tories of these particles. A typical example is the tra-y of a high-speed electron in a nonlinear electric field. quation of motion in the particular direction X is

$$\frac{nv)}{lt}$$

e $\mathcal{E}$ is the electric field intensity; m is the mass of the ron; v is the velocity of the electron; and t is time. preceding equation becomes

$$\frac{v}{t}$$

t in applications where electron velocities approach peed of light, in which case

$$\left(\frac{m_0 v}{\sqrt{1-\left(\frac{v}{c}\right)^2}}\right)=m_0\left[1-\frac{v^2}{c^2}\right]^{-3/2}\frac{dv}{dt} \qquad (9)$$

where m_0 is the rest mass of the electron and c is the velocity of light. For an application of practical interest $\mathcal{E}$ varies in magnitude with distance x and sinusoidally with time; hence the relation

$$\mathcal{E}=E(x)\sin\omega t$$

where $E(x)$ is obtained from test data.

Combining this with equation 9 and integrating

$$v=\frac{1}{m_0}\int\left[1-\left(\frac{v}{c}\right)^2\right]^{3/2}E(x)\sin\omega t\,dt$$

$$=\frac{-1}{m_0\omega}\int\left[1-\left(\frac{v}{c}\right)^2\right]^{3/2}d\int E(x)d\cos\omega t \qquad (10)$$

Equation 10 is solved on the analyzer as shown in Figure 7. Solutions for various field conditions are shown in Figure 8.

The mechanical differential analyzer is capable of solving problems which can be formulated in terms of linear or nonlinear ordinary differential equations with constant or varying coefficients. Certain types of partial differential equations also can be solved on the differential analyzer by special techniques. There are now other computers which possess either greater speed, accuracy, or versatility in particular instances. However, because of its particular combination of these features it is the most suitable computer to employ for a large variety of problems and continues to be of great assistance to present-day technology.

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Balancing Large Turbine-Generator Rotors

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SINCE turbine-generator rotors are highly stressed structures that combine materials of widely varying properties, unbalance may be caused by geometrical errors, nonhomogeneity of materials, or distortion under the speed and temperature of operating conditions. The purpose of balancing is to offset these imperfections by adjustment of the rotor mass distribution so as to secure a rotor which will run so smoothly that only small periodic forces will be transmitted to the supporting bearings and foundation.

With the ever-increasing requirement of larger units to meet power demands, balancing problems have become greatly accentuated during recent years. Consequently, in order to maintain the high degree of rotor quality required for continuous reliable service without introducing serious production delays, modern practice must be able to deal effectively with all the various unbalance conditions.

Following the primary control of materials and manufacture, balancing and seasoning are performed in test rigs, Figure 1, that approximate as closely as feasible the characteristics of the assembled unit on the customer's foundation.

As part of the normal shop-balancing procedure the rotor is heated to a uniform temperature of 130 degrees centigrade in a heater box, shown in open position in Figure 1, and balanced to its normal operating speed. Since the operating speed of large rotors normally lies between the first and second critical speeds, recourse usually is made to five balance planes to obtain the best mass distribution. Vibration readings are checked at six points along the shaft.

For accurate and reliable determination of the amplitude and phase of unbalance vibration, extensive use is made of the wattmeter-type balancing equipment incorporating electromagnetic pickups and a direct-coupled sine-wave generator. The pickups, applied directly to the shaft through suitable carbon followers and lightweight pushrods, may be used seismically, Figure 1, to expedite the servation of rotor performance through test cycles.

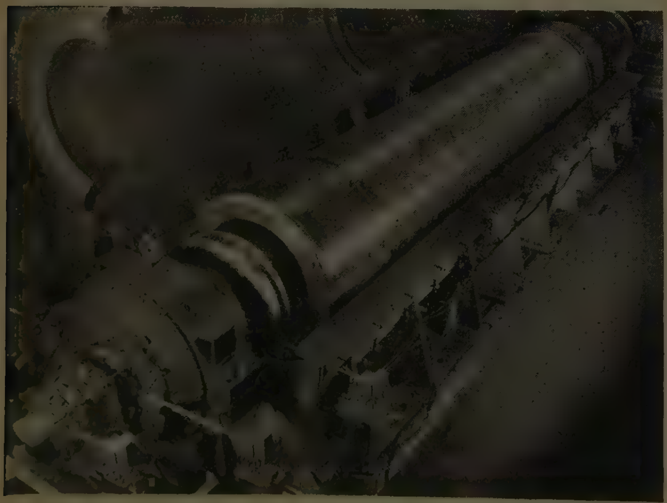

Figure 1. Test rig for balancing large rotors

For field conditions, a hand-held sine-wave generator been developed, which may be clutched directly to rota shafts, to check generator vibrations without shutdo

To insure that complete adjustment of the various c ponents and the insulation has taken place, the roto seasoned for eight hours at full speed and temperature given a shakedown run at 110 per cent of normal sp This procedure has been proved effective in produ rotors which remain stable during normal operation.

After a final touch-up balance the rotor vibrations checked in both the hot and cold conditions to uncover tendency for thermal variations. With the present- equipment and techniques, the normal balancing and soning period for large rotors averages approximately days. This represents a considerable reduction from three to five weeks once required.

Occasionally, cases are experienced where a chang balance occurs with a change in rotor temperature. mally, these isolated cases arise from a slight bowing of shaft such as might be produced by minor tempera variations across the diameter of the rotor or by differen expansion of the several dissimilar materials.

If the observed change is small, it is possible to ma compromise mechanical balance such that the thermal passes through zero while maintaining the maximum am tudes of vibration within acceptable limits. If the cha is excessive, however, it is possible to balance the r thermally by another method. Thermal balancing, in case, consists essentially of neutralizing troublesome perature distortion of the rotor by effectively introduci counter bowing by means of an artificial tempera gradient across the diameter of the rotor. This may accomplished simply by minor adjustments in axial ven tion using special silicone rubber plugs.

In addition to the control of unbalance vibration, pr dures and techniques also must be adequate to cope other vibration problems such as may arise from the fo vibrations of rubs and minute variations in journal tours or from the self-excited vibrations of subharm resonance and oil whip.

Coupling the generator rotor to the turbine rotor alter, in general, the critical speeds of the combined somewhat, but the amplification factors at the opera speed will be essentially the same. Consequently, if component is properly machined, seasoned, and balar the assembly also will be in balance.

Digest of paper **51-97**, "Modern Practice in the Balancing of Large Turbine-Ge Rotors," recommended by the AIEE Committee on Power Generators and appro the AIEE Technical Program Committee for presentation at the AIEE Winter C Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in *Transactions*, volume 70, 1951.

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An Electromechanical Transducer

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As the telemetering art progresses under the impetus of both aircraft and industrial needs, the requirement for accurate transducing becomes more and more important. This article describes a null-balance type of transducer which is inherently capable of achieving an accuracy comparable to that of present-day transmission links.

NY TELEMETERING SYSTEM which accomplishes the indication or recording of a physical quantity at a remote point is usually considered to consist of major components: (1) the measuring and trans- g device, (2) the transmission system, and (3) the end e.

e main transmission systems that are being used today oe divided into five gen- roups: the current, volt- frequency, position, and -time systems. Their s indicate the type of ic signal which is used to mit information about nagnitude of a physical tity from the point where neasured to the remote n where it is converted n indicating or recording l. For the sake of completeness, it should be men- d that transmission also could be in other than electri- rms, such as pneumatic or hydraulic, but these will not nsidered here.

e task of the measuring and transducing device is, then, f changing the measured variable into the particular ic signal selected for the transmission system. Except e special cases where current or frequency themselves proper range are to be measured, or where the change rrent or frequency could be accomplished by an elec- etwork only, a transducing device is necessary. This des not only the obvious cases of measuring displace- s or forces but also many electrical quantities which re- an intermediate transducing device to express them rms of the electric signal chosen for transmission.

MECHANICAL DESIGN

HE ELECTROMECHANICAL transducer described here hanges mechanical and certain electrical quantities orresponding electric current, mainly for purposes of te transmission. Operating on the principle of a con- us torque balance, the Microsen Balance actually is a servomechanism which, because it uses an external r supply for its operation, is also capable of raising ower level of the input signal. For electrical inputs, fore, it becomes an electromechanical amplifier whose cteristics already have been described briefly and n will be discussed here in greater detail.

First, with reference to Figure 1, a qualitative description of the transducer shall be presented. The Microsen Balance is a compact torque balance device which was designed to have the sensitivity of a galvanometer while being rugged enough to withstand stringent field conditions. As shown, the torque measurements are made on a balanced-beam structure wherein mechanical torques are applied through a hairspring at the fulcrum of the beam and wherein electric currents produce torque in the coil suspended in the efficient pot-type magnet. The beam floats whenever the applied torques completely balance to zero. Input to the electromechanical balance is either mechanical rotation of the hairspring or direct current running through one of the coils on the end of the beam. In any case, the beam is brought to balance by a current in the feedback coil, this current being proportional to the output electric signal. Accordingly, whenever the beam is floating, the transducer is putting out an electric signal proportional to the input signal, whether the input is electrical or mechanical.

ELECTRONIC CIRCUIT

THE ASSOCIATED electronic circuitry is relatively simple. Assuming a d-c power supply, the circuit of Figure 1 employs only one tube in a bridge circuit. Bridge unbalance is the output as well as the feedback signal.

The tube is operated as a 40-megacycle tuned-plate tuned-grid oscillator which is self-biasing. Control of the intensity of oscillation is effected by the flag on the end of the electromechanical beam structure. This flag, moving over a total distance of approximately 0.010 inch, has complete control of the oscillator output. When the flag is nearest the pancake-type grid coil, the oscillator is out of oscillation; as the flag moves away from the grid coil, oscil-

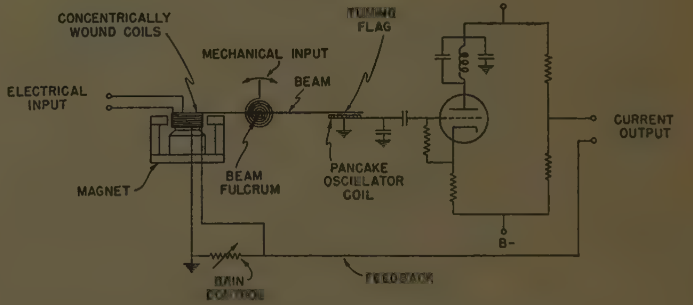

Figure 1. Schematic wiring diagram of transducer

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t of paper **51-29**, "An Electromechanical Transducer," recommended by the Committee on Instruments and Measurements and approved by the AIEE al Program Committee for presentation at the AIEE Winter General Meeting, rk, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transac-* lume 70, 1951.

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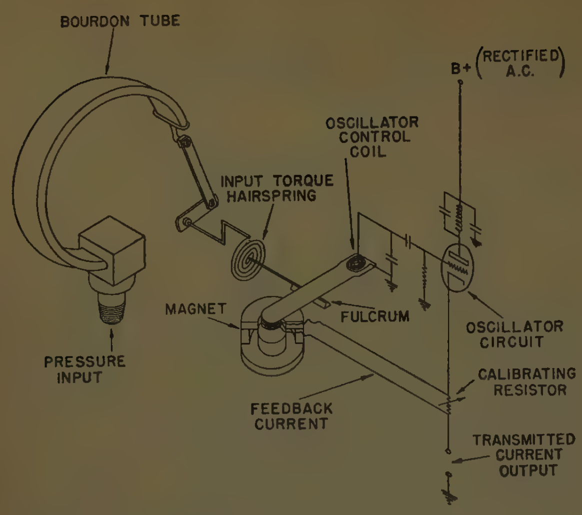

Figure 2. Transducer used as pressure transmitter

lation begins and becomes proportionally stronger. The d-c impedance of the tube in the bridge circuit varies with the intensity of oscillation, since the grid leak on the tube supplies negative bias in proportion to the oscillator output.

Thus, what is effectively being done is that the flag is varying a resistor in a bridge circuit over the range of 3,000 to 20,000 ohms with no significant force being required in the accomplishment.

It becomes evident that one possible means of transducing would be merely to have the input motion position a flag with respect to a pancake coil and then consider the bridge output as the transduced signal. The frailty of such a setup lies in the fact that other factors besides the flag motion can affect the output; such things as supply voltage and ambient temperature changes may cause appreciable shifts in the output.

This last point constitutes the main reason for including the feedback link and an electromechanical transducer which continuously measures both input and output signals and arrives at a null balance between them by controlling the output signal. This null-detection principle eliminates dependence upon variations in the electronic circuit, the accuracy of transducing being a function merely of the sensitivity of the torque-balance device.

TRANSDUCING APPLICATIONS

BEFORE GOING into a more rigorous analysis of the characteristics of this transducer with regard to its servo stability criteria and ultimate accuracy, a brief description of some typical applications will be presented.

In Figure 2 the transducer is shown as a pressure transducer with a Bourdon tube supplying the input signal. Since the torque applied to the beam through the hairspring is proportional to the pressure being measured, when a torque balance is obtained the output current is proportional to pressure. This scheme is typical wherever the signal being transduced may be translated into rotary motion.

When the transducer has an electrical input, strictly speaking it is not a transducer at all but a d-c amplifier. Low-level direct currents, such as from thermocouples and strain-gauge bridges, may be amplified very accurately useful telemetering level. Zero drift characteristics wholly electronic d-c amplifier are not present since the f back link goes back to the balance where output and in current are compared continuously in the same magn field.

One feature of this electromechanical d-c amplif principle is that part of the input range may be suppre by means of the hairspring at the beam fulcrum. example, if the temperature band of interest for a teleme ing channel were from 1,000 to 1,500 degrees Fahrenh the first 1,000 degrees could be suppressed, with the en output being available for the desired temperature ba Another point, sometimes valuable, is that the input cir is completely isolated from the rest of the amplifier.

It should be noted, however, that this unit does req current in order to develop a measurable torque; theref it is not useful with high-impedance-input devices suc piezoelectric crystals.

The transducer also can be used as a computer. possible to add and subtract both electric and mechar signals. Because the coil in the magnetic field is wo round, as is a loudspeaker voice coil, it becomes conven to wind a number of concentric coils on the same form thereby allow simultaneous additive or subtractive electr inputs which are isolated from each other. Mechar inputs at the fulcrum obviously can also be additive or tractive. With any combination the feedback torque ances out the net resultant torque of all the inputs, and output is proportional to this resultant.

ACCURACY

NOW AN ATTEMPT shall be made to set up the fur mental relationships governing the over-all accu of this transducing means and to present an analysis o unit's stability criteria and frequency-response chara istics. The symbols used in this analysis will be those es lished in Figure 3 and listed here.

J, gram-square centimeters, is the inertia of the beam
R, dyne-centimeters per radian per second, is vel damping
C, dyne-centimeters per radian, is the spring rate
θ_i, radians, is the input angle to hairspring
θ_o, radians, is the deflection of beam
T_i, dyne-centimeters, is input torque to beam
T_o, dyne-centimeters, is feedback torque to beam
I_o, milliamperes, is current output of amplifier
E_o, millivolts, is voltage output of amplifier

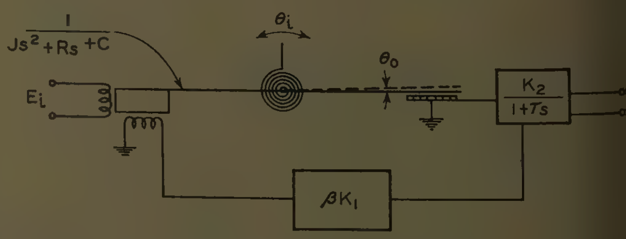

Figure 3. Operational schematic. There are three po torque inputs: (A) direct torque application to beam, (B) current producing torque in coils, and (C) angular displacem hair spring

liamperes, is current input to amplifier
llivolts, is voltage input to amplifier
yne-centimeters per milliampere, is feedback torque
er unit of current
tio of feedback to output current
$\cong K_2$ when the output current is the beam deflection
onds, is the time constant
(s) are transfer functions (see equation 1)

considering the steady-state accuracy of the transducer, licrosen beam is assumed to be an approximation to a letector that compares the input with the feedback e. Since the beam is not a perfect null detector, the nt must be expressed as

$$(\theta)\theta_o + K_3$$

this expression $K_2(\theta)\theta_o$ represents the characteristic of output current versus beam angle, while the con- term K_3 represents extraneous shifting influences such e-voltage variations or tube-characteristic changes. gure 4, an I_o verus θ_o curve is shown. As a typical ex- e of the magnitude which may be taken by the extra- shifting influences, curves are plotted showing the in the characteristic with normal line-voltage varia-

is evident that the approximation to a null detector nes better as the total θ_i used becomes larger with re- to the total θ_o necessary to swing through the entire it-current range. Based on the total input angle, the ntage error resulting from shifts in the output char- istic may be expressed as

nt error $= 100\ \Delta\theta_o/\theta_i$

$\Delta\theta_o$ is the change in beam angle required to return it to the same level that existed before the shift oc- d. Thus, noting in Figure 4 that the maximum shift ing from line-voltage variation is 0.15 angular degree assuming a total input angle of 30 degrees, the per- ge error would be 0.5 per cent.

FREQUENCY RESPONSE

INVESTIGATE stability and frequency response, the ransfer functions of the system are written as

$$\frac{}{\ _o} = H(s) = \frac{K_2}{(Js^2+Rs+C)(1+\tau s)}$$

$$(s) = \beta K_1 \qquad (1)$$

ould be noted that in the foregoing transfer functions s been neglected since the long time shifts are not sig- ant in analyzing system stability. Further, for the of simplicity, K_2 is assumed to be a constant. This is tially true for small deflections.

cause input is torque and output is current, $H(s)$ and are not dimensionless quantities.

investigate stability, we can write the loop transfer ion as

$$(s) = \frac{\beta K_1 K_2}{J} \frac{1}{\left(s^2+\frac{R}{J}s+\frac{C}{J}\right)(1+\tau s)} \qquad (2)$$

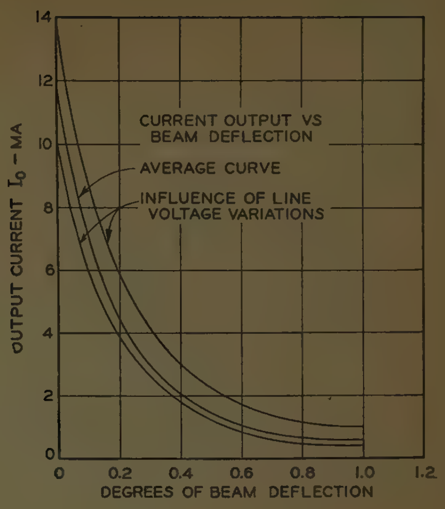

Figure 4. Characteristics of null detector

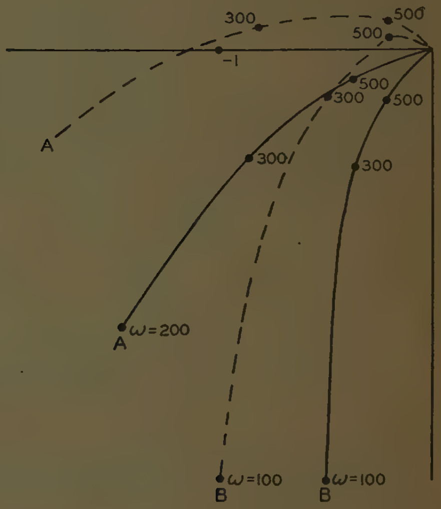

Figure 5. Stability of d-c amplifier

Examination of equation 2 shows that without the time constant τ of the electric amplifier, the transducer would always be stable. However, due to this delay, $\beta K_1, K_2/J$ has to be limited to obtain a safe margin of stability.

As an example, the case of a voltage amplifier will be treated. The input voltage E_i is being introduced into the transducer in the form of current-producing torque (case *B*, Figure 3). Part of the output voltage is being fed back into another coil in the same magnetic field, producing the restoring torque.

Neglecting *C*, which is the torque of a small zero-adjusting spring and the current-carrying leads, we can see in Figure 5 $H(s)$ $G(s)$ both with and without the delay of the electronic amplifier. The ratio β is adjusted so as to give a voltage a gain of 100.

A delay of 0.0025 second in the oscillator circuit and amplifier will make this system unstable if the damping reduces below the critical value.

The value of the loop gain and the damping is of equal importance in determining the frequency response of the transducer.

Using the inverse plane method from equation 1 the following equations are obtained:

$$\frac{T_i}{I_o} = \frac{1}{H(s)} + G(s)$$

$$\frac{T_i}{I_o}=\beta K_1+\frac{J}{K_2}\left(s^2+\frac{R}{J}s+\frac{C}{J}\right)(1+\tau s) \tag{3}$$

Neglecting τs for first approximation and setting $C=0$ as before

$$\left|\frac{T_i}{I_o}\right|^2=\frac{\omega^2}{K_2}(R^2-2JK_1K_2\beta+\omega^2J^2)+K_1^2\beta^2$$

R is chosen so that $R^2-2JK_1K_2\beta$ becomes zero, which is equivalent to critical damping.

$$\left|\frac{T_i}{I_o}\right|^2=\frac{J^2}{K_2^2}\left(\omega^4+\frac{K_1^2K_2^2\beta^2)}{J^2}\right) \tag{4}$$

This condition cannot be realized for all values of $2JK_1K_2\beta$ because R is obtained directly only through electrodynamic damping.

Interpreting equation 4, the frequency response will be flat as long as

$$\omega^4<<\frac{K_1^2K_2^2\beta^2}{J^2} \tag{5}$$

$K_1K_2\beta$ is the feedback torque produced per radians deflection of the Microsen beam and $K_1K_2\beta/J$ can be called the torque-to-inertia ratio of the system which, in turn, determines the frequency response. However, because of the delay τ, this torque-to-inertia ratio must be kept below a value which will cause instability. Moreover, the frequency-response curve is altered slightly by the addition of $(1+\tau s)$ in the equation. This is illustrated in the following paragraphs.

Using the same example of a voltage amplifier with a gain of 100, Figure 6 shows the frequency-response curve on the inverse plane with and without the delay. Curve B shows the values for critical damping, Curve A for slight underdamping, which is on the borderline of stability, and Curve C for overdamping.

This frequency response is adequate for the d-c amplifier and transducer applications for which this instrument was developed. However, this analysis suggests various methods of improving this response by introducing corrective networks in either the $H(s)$ or $G(s)$ functions. In order not to impair the steady-state accuracy, only passive networks must be introduced into $G(s)$.

CURRENT TRANSMISSION SYSTEM

AT THE OUTSET it was mentioned that there are basically five established approaches to electric telemetering: the current, voltage, frequency, position, and pulse-time systems. Up to this point, the Microsen Balance has been
considered only as a transducer supplying a signal at a l
useful as an input to a telemetering channel. A signa
five direct volts can be converted readily into a freque
shift in a frequency-modulated channel, for example.

However, it should be recognized that this transdu
also represents a transmitter for the least complicated of
five transmission techniques, the current-transmission
tem. In closing this discussion, the particular charac
istics of d-c transmission will be considered.

Because the direct current is transmitted directly, a
metering system of this type requires two wires betw
transmitter and receiver for each variable. Although
eral transmitters could use a common ground return,
apparent that this system of telemetering is restricted
those applications of moderate distances where wiring
not constitute a great expenditure.

Wherever a number of signals must simultaneously
transmitted over some distance, a multichannel system
comes imperative. However, where it is applicable,
rent transmission offers compensation in its great simplic
especially at the receiving end.

Next to the domestic watt-hour meter, the d'Arson
type d-c milliammeter is the most widely used electric
strument. It exists in a great variety of types ranging f
inexpensive small meters to precision laboratory ins
ments. During the last few years a number of instrum
with 250-degree dial arcs have contributed to increa
readability and thereby greater usefulness in industria
stallations. All these instruments are directly usable a
ceivers in this current system; it is necessary only to sele
range to match that of the transducer.

For recording, any of the various self-balancing pote
ometer recorders may be used with a d-c signal. This po
up one significant advantage of current transmiss
Standard multipoint recorders may be used for surve
a number of variables. This reduces end-device costs
permits more compact control-house layouts.

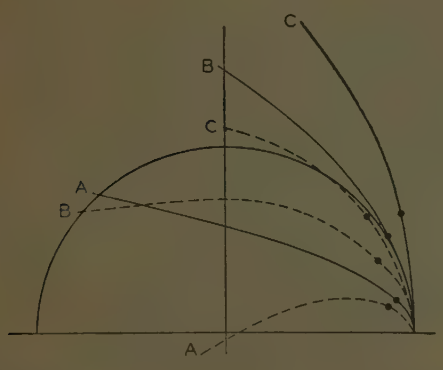

Figure 6. Frequency response of d-c amplifier

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Disturbance of Feedback Controllers

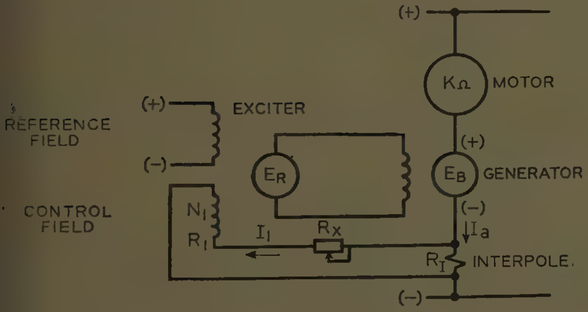
R. W. JONES
MEMBER AIEE

HE FUNCTION of many industrial regulating systems is to hold some process quantity reasonably constant he face of a diversity of disturbances which would rwise cause that quantity to vary with time in an unptable manner. While such systems operate by eloping corrective measures which are of opposite sign he errors in the regulated quantity, the reference ntity, which is usually thought of as the standard of parison, frequently does not appear explicitly.

1 such a system the principal problem is that of miniing the effects of such disturbances as changes in bus ages, prime mover speed, and field heating. A ful analysis of such effects shows that they cannot be sidered simply as additional forces imposed upon the em, but that they may appear in a number of forms. h reference to the set of equations describing the system amics it is found that these disturbances may:

. Change the coefficients of one or more terms in the of equations.
. Add constant terms to the equations, or change the ie of certain constant terms.
. Add equations to the original set.

: is seen that these disturbances actually change the set quations in several ways, and hence a consideration of disturbances must be based upon both the old and the set.



re 1. **Current regulating system using a buck-boost generator**

he current regulator shown in Figure 1 may be used as example. The buck-boost generator serves to increase counter electromotive force of the circuit as the current eases. If the machines operate in the saturated on of the magnetization curve, the graphical construction of Figure 2 may be used to locate the operating point. If the resistor R_x is used as a means of gain adjustment, then the characteristic in the first quadrant will change from Curve 1 to Curve 2 as the gain is increased. But this change in gain also effects the operating point unless a corresponding change is made in some other element in the system. The reference field of the exciter is used for this purpose, which is equivalent to using characteristic 3 in the first quadrant. This example serves to illustrate the fact that when a regulating system operates without an explicit standard for comparison purposes, the operating point is determined by all the elements in the circuit, and a change in any one of these elements will move the point of operation.

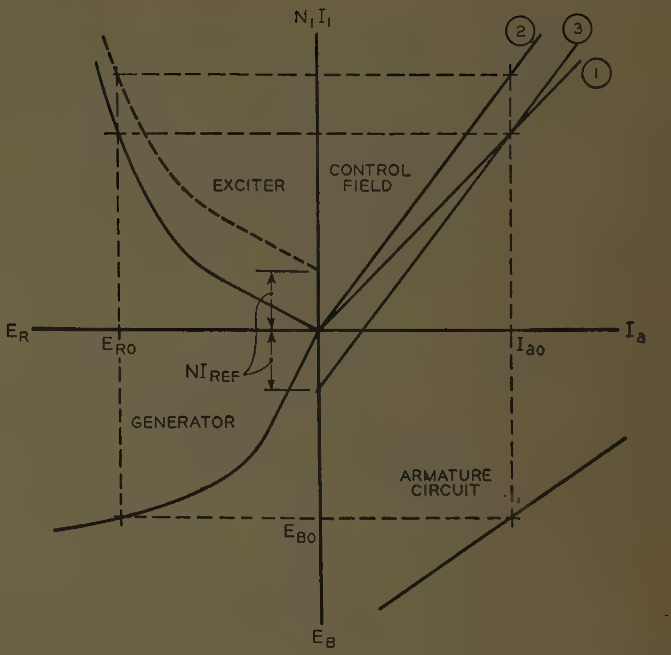


Figure 2. Graphical construction for finding equilibrium values in a nonlinear system

Disturbances or loads on the system will in some manner modify one or more of these characteristics and thus change the operating point. This matter may be studied by making another construction similar to Figure 2 using the modified characteristics. Conversely, knowing the permissible change in the operating point as a result of all disturbances, the necessary system gain can be computed from such a diagram. This is accomplished by constructing the two extreme characteristics in each quadrant whose positions will be set by the disturbances under consideration. The permissible change in operating point then determines a band which may be traced backwards through quadrants 4, 3, 2, and 1 where this bandwidth together with the permissible change in operating point will determine the necessary system gain.

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t of paper **51-73,** "The Effects of Loads and Disturbances upon Feedback Conrs," recommended by the AIEE Committee on Feedback Control Systems and oved by the AIEE Technical Program Committee for presentation at the AIEE er General Meeting, January 22–26, 1951. Scheduled for publication in AIEE *actions,* volume 70, 1951.

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Response of Saturable Reactor with Resistive Load

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THIS ANALYSIS deals with saturable reactors whose core material can be approximated by a rectangular magnetization curve. Such response is analyzed with respect to changes of control voltage, supply voltage, and load resistance. Operating in the proportional region, the response of the load current to any of the previous changes is an exponential function, governed by a single time constant, which varies with the load and inversely with control-circuit resistance and line frequency.

SERIES-CONNECTED SATURABLE REACTOR

DESPITE instantaneous variations of the magnetic flux in both magnetic circuits of the saturable reactor, the total flux linkage Ψ_C with the control winding is time invariant during steady-state operation. The magnitude of Ψ_C depends upon the control voltage E_C, the line voltage E, the load resistance R_L, and the supply frequency f.

If any of these parameters changes, a new level for Ψ_C will be finally established. Because Ψ_C cannot change in zero time, the new steady-state operation cannot be immediately attained and a transient results.

The transient affects Ψ_C, control and load current, and is exponential, governed by the time constant T:

$$T=\frac{1}{4f}\frac{R_L}{R_C}\frac{N_C^2}{N_L^2}\text{ seconds} \tag{1}$$

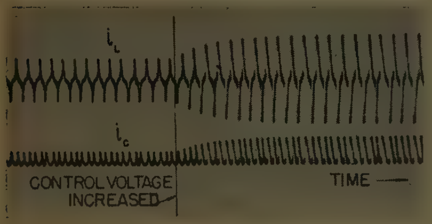

Figure 1(A). Oscillogram of load current i_L and control current i_C when control voltage is increased

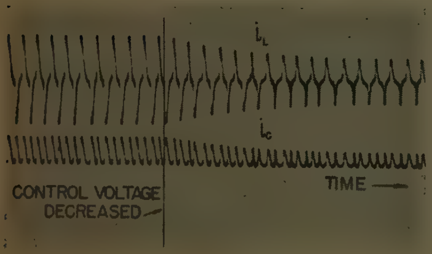

Figure 1(B). Oscillogram of load current i_L and control current i_C when control voltage is decreased

where R_C is the resistance of the control circuit, N_C is the number of turns of the control winding, and N_L is the number of turns of the load winding.

If the control voltage E_C is suddenly raised, the load current and control current will rise exponentially as shown in Figure 1*A*. Similarly, they fall exponentially when the control voltage is lowered (Figure 1*B*). By plotting the average value of load current in each half-cycle on semil paper (Figure 2) a check is obtained with respect to the e ponential character of the transient.

A sudden increase of line voltage will cause a sharp, tra sient increase of load current and control current which m cause damage to instruments. A sudden reduction of lo resistance will cause a transient increase in load curre thus temporarily wiping out the current-limiting charac of the saturable reactor.

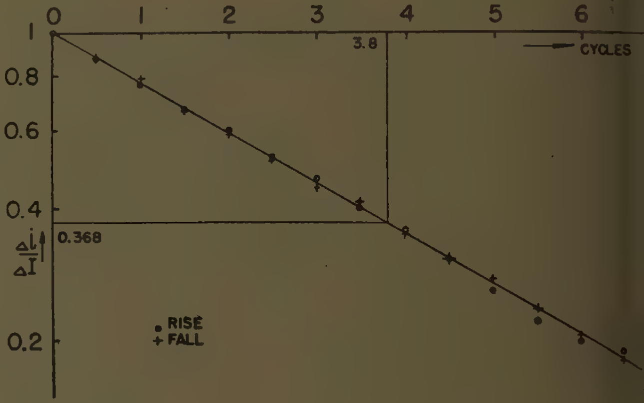

Figure 2. Relative load current changes over one-half cy Solid line represents calculated values, dots and crosses den measured values

Defining the power gain K_p of the saturable reactor the ratio of power output over power input, the ratio K_p/T becomes:

$$K_p/T=4k_f^2\text{ per cycle}$$

where k_f is the form factor of the load current and varies tween 1.11 and 1.5. Equation 2 is very important, partic larly in connection with servomechanism work, because t transfer function of the saturable reactor now can be writt without the knowledge of any details about the satura reactor.

PARALLEL-CONNECTED SATURABLE REACTOR

WITHOUT AN external resistance in the control windi the time constant of the parallel-connected satura reactor is usually twice the time constant of the seri connected reactor. If resistance is added to the cont circuit of the parallel-connected saturable reactor, its ti constant becomes smaller but cannot be reduced below o half of its highest value.

Digest of paper 51-13, "Transient Response of Saturable Reactors with Resistive Lo recommended by the AIEE Committee on Industrial Control and approved by AIEE Technical Program Committee for presentation at the AIEE Winter Ge Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in A *Transactions*, volume 70, 1951.

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The Power Interruption Testing of Lightning Arresters

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A special surge circuit has been developed for use in power interruption testing of lightning arresters. This circuit consists of a power source, a surge circuit, and an impulse timing circuit.

LIGHTNING ARRESTER is a device which permits a practically unrestricted flow of electric current between its line and ground terminals when the nal voltage becomes a certain multiple of its rated ge, and which interrupts the flow of current when the oltage has passed. The interruption preferably d take place when the power current goes through or the first time after the oltage has disappeared. is phase of their operat-ycle lightning arresters rm as circuit breakers. is observation applies lve-type and expulsion-ightning arresters alike.

difference as inter-ng devices lies in the manner in which they influence power-follow current before current zero occurs. -type lightning arresters have a nonlinear resistance cteristic chosen so that the resistance at rated voltage y large compared to the reactance of any ordinary source. Therefore, the power current flowing gh a valve lightning arrester is practically in phase the generated voltage. For this reason the current is interrupted rather easily at current zero. The uption is accomplished by a series gap structure consists of a number of closely spaced metal elec-s. The more the current is restricted by the valve n, the easier is the duty on the gap section as an upting device. Power-follow currents in valve light-arresters are of the order of 10 to 100 amperes.

ne types of expulsion lightning arresters, particularly for transmission-line protection, constitute the other ne in the spectrum of interruption processes. The rop in such devices is so low that the power-follow nt is determined almost entirely by the system itself. ost cases the system short-circuit current is pre-rantly reactive; hence current zero occurs near the of the generated voltage. Therefore, the recovery tions are severe. The clearing action takes place ly in the arc channel of the expulsion device and at ctrodes; the series gap is not counted upon to con-e to the extinction process. It merely serves to te the expulsion device from the line while normal e voltage only is present.

some expulsion lightning arresters for distribution service, the arc voltage developed in the deionizing channel becomes an appreciable part of the service voltage. In these cases, therefore, the expulsion lightning arrester actually limits the power-follow current, and it becomes, in this respect, more like a valve-type lightning arrester, but with one fundamental difference always remaining. In expulsion lightning arresters the series gap plays no part in the current interruption, while in valve-type lightning arresters the series or quench gap takes over at least part of the interrupting duty. That the series gap of expulsion lightning arresters cannot be expected to assist in the current interruption becomes evident if one considers the recovery characteristics of rod gaps on which very interesting information has been presented to the members of the Institute recently.[1]

When testing lightning arresters for their power-current interrupting ability, the discharge usually is started by a surge generator. The surge, however, is not always followed by power current. The establishment and the severity of power current after a surge depends on the following factors:

1. Amplitude and wave shape of the surge.
2. Timing of the surge with respect to the 60-cycle voltage.
3. Voltage and current output of the power source.
4. Power factor between generated voltage and bolted fault current.
5. Circuit recovery voltage.
6. Characteristics of the interrupting device.

The importance of these features in duty-cycle testing of lightning arresters has long been realized, and they have found recognition in the various standards.[2–4] Therefore, adequate test circuits must contain means for controlling these factors.

A basic circuit which incorporates these features is shown in Figure 1. The circuit consists essentially of three sections:

1. The power source with series reactance L_1, resistance R_0, and shunt capacity C_2 to control short-circuit current and recovery voltage.
2. The surge circuit comprising surge generator, test piece, and separating gap.
3. The impulse timing circuit.

A special circuit for impulse timing has been developed

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text of paper 51-1, "The Power Interruption Testing of Lightning Arresters," ended by the AIEE Committee on Protective Devices and approved by the echnical Program Committee for presentation at the AIEE Winter General , New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *ons*, volume 70, 1951.

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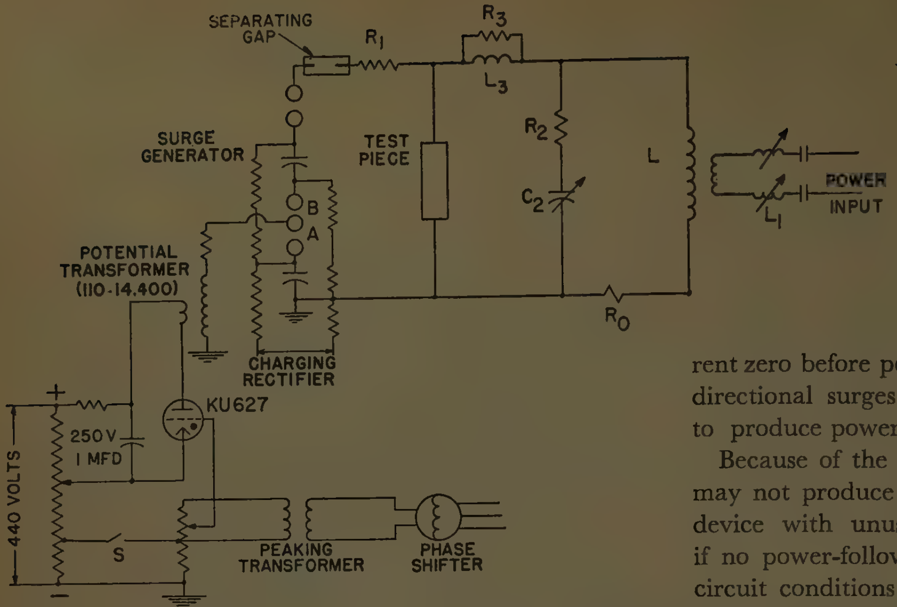

Figure 1. Basic circuit for the power interruption testing of lightning arresters

and is widely used. It is shown in the left-hand lower portion of Figure 1.

The key to the circuit is the 3-electrode gap *A-B*. When the surge generator is charged, the full voltage of the first capacitor unit appears across the gap *A* since the center electrode is grounded through an unenergized transformer. This gap is adjusted to spark over at a potential 10 to 20 per cent above the surge-generator charging voltage. The necessary increment in voltage, which must be opposite to the polarity of the charging source, is obtained by shock excitation of the potential transformer. Gap *B* must be set so that the transformer surge alone does not break it down; this should be checked with the surge generator de-energized. On the other hand, the setting of gap *B* must be smaller than that of gap *A*. With the gaps co-ordinated in this manner, *A* will spark first and *B* will follow within a fraction of a microsecond. The signal impulse in the potential transformer is produced by the discharge of a capacitor, which in turn is timed by a thyratron tube. The grid of the latter normally is kept at a direct potential so low that even the continuously superimposed voltage from the peaking transformer will not unblock it. However, if the bias level is decreased by closing the switch *S*, the first following peaking impulse of the proper polarity will open the valve. The peaking transformer is energized from a phase shifter which ties in with the power supply to the lightning arrester under test.

The surge circuit consists of the surge generator capacitors, the series resistance R_1, the test piece, and the separating gap. The function of the latter is to insulate the surge generator from the power circuit after the surge discharge. An ordinary rod gap, set as high as the surge generator voltage will permit, is sufficient in many cases. In others it is necessary to employ a regular deionizing gap. A device similar to the test piece itself often answers the purpose.

The resistor R_1, which stands
the total damping and series res
ance, has the purpose of regula
intensity, duration, and wave sh
of the discharge. Heavy osci
tory surges should be avoided si
they may constitute an unusu
favorable condition for the de
to clear because of the expuls
action created by the surge or
cause of the introduction of a c
rent zero before power-follow current is established.
directional surges of moderate current are most lik
to produce power follow.

Because of the various circuit conditions which may
may not produce power follow,[5] it is not safe to credi
device with unusually good performance characteris
if no power-follow current can be obtained, even thou
circuit conditions may have been varied to some exte
one can be almost certain that within the unlimi
combinations of surge and power occurring in the fi
power-follow current will be established under sc
conditions. Then the device whose design has gr
around no power-follow test conditions may find i
in a situation which it is not equipped to handle. Th
fore, in the testing of protective devices one should expl
all reasonable means, such as controlled timing and va
tion of length and intensity of the surge current, to m
the test piece take power follow.

In order to obtain the maximum severity discha
from a given power source, the various standards stipu
that the current flow be started as early as possible in
cycle of the generated voltage. Starting the discharg
the zero point of the generated voltage theoretic
produces the longest duration of power-follow current
to the next current zero, and it also will produce the hig
current peak. In practice, however, it is difficult, an
lightning arresters with very effective deionizing act
even impossible, to start power follow at the zero of ge
ated voltage. The setup which will operate most c
sistently usually is one in which the discharge is initiated
to 30 degrees after that moment.

The amplitude of the first current loop is influenced
only by the timing of the starting impulse, but also by
power factor of the circuit and by the arc voltage develo
by the lightning arrester. If a current has zero per
power factor, which implies that there be no losses at
in the circuit and hence no decrement in the d-c compon
and if the discharge is started at the zero point of
generated voltage, the peak current will be twice
symmetrical crest value. This is the condition represe
by the start of both curves *A* and *B* in Figure 2. If
power factor is increased while the symmetrical
current is maintained by corresponding adjustment
the circuit reactance, the obtainable current peak decre
as shown by curve *A*. This illustrates how the seve
of tests at plants set for the same symmetrical cu
output can be affected by the power factor. If, on
other hand, the reactance of the power source rem
fixed and the power factor is increased by adding resista

obtainable peak current changes as shown by curve *B*.
curve illustrates, for instance, how drastically even
erate circuit or ground resistance reduces the service
of an expulsion lightning arrester below what would
xpected on the basis of bolted fault calculations made
considering the circuit reactance only, which is done
e frequently. It also illustrates in an approximate
ner the beneficial effect of high arc drop in expulsion
tning arresters. A rigid analytical treatment of this
ect was presented by Boehne a decade ago.[6]

he curves *A* and *B* in Figure 2 whose formulas are
ented in AIEE *Transactions*[7] are drawn up for conditions
n the power-follow current is started at the zero point
he generated voltage. As mentioned before, this is a
ewhat hypothetical case because lightning arresters
likely to suppress power current under that condition.
ne discharge is initiated β electrical degrees later, the
t current ratio at zero power factor, instead of being
al to 2, will be $1+\cos\beta$, which is 1.985, 1.94, and 1.87
$\beta=10$, 20, and 30 degrees respectively. The curves
nd *B* for the various timing angles would start, therefore,
he values quoted and would end up coinciding with the
inal curves at 100-per cent power factor. It is evident
the deviations from the original curves are small and
the latter can be used with little error for the purpose of
analysis. One of its objects is to show that for strictly
parative tests it is not enough to have the power sources
usted for the same symmetrical rms current, but that
power factors also should be held within reasonably
row limits.

ir-core reactors are the most suitable primary means
controlling the test current. They are represented by
n Figure 1. The power factor is increased by inserting
resistance R_0. This resistance, as well as L_1, may
placed in either the input or the output side of the
ver transformer.

he recovery voltage also must be subject to control,
he natural frequency of unmodified test circuits usually
oo high to be representative of the service conditions
which protective devices, particularly of the expulsion
e, are designed. The frequency of the recovery voltage
ontrolled by the variable capacity C_2, and its amplitude
R_2[11] and by R_0. The latter affects the phase angle and
reby the instantaneous value of the generated voltage to
ch the circuit tries to recover.

t has long been established by studies on the recovery
ditions on power systems[8–10] that the recovery voltages
ountered usually are not of a single frequency. The
n features of their rather variable pattern have been
cribed by giving voltage and time for first and second
st,[8] or by the time to 90 per cent of normal, and to max-
m voltage.[9] While circuits of such characteristics
readily be set up on analogue computers, it commonly
mpractical to duplicate them in power laboratory
s. It is, of course, essential that the recovery conditions
ountered in the field be known, but they need not
duplicated in testing. It is satisfactory if the test cir-
comes reasonably close to field conditions, or better
if it is somewhat more severe so it will demonstrate an
rating margin. It usually is not difficult to set up a circuit which, although it has only one recovery frequency, fulfills these requirements sufficiently well.[11] The time *T* from current zero to recovery voltage crest can be predicted with fair accuracy by considering it to be equal to one-half cycle of the natural frequency of the circuit:

$$T=3.14\sqrt{LC_2}$$

where *L* is the reactance of the power supply in henrys. Expressing *L* in terms of the reactive short-circuit current *I* and of the plant voltage *E*, the shunt capacity required in the case of 60-cycle power becomes

$$C_2=T^2\times 38.2\ I/E\ 10^{-6}\ \text{microfarads,}$$

where *T* is expressed in microseconds.

The addition of such capacity to the test circuit always poses certain difficulties. Being in parallel to the test piece it increases appreciably the demand on the surge generator output required to produce spark-over and, after spark-over, it may cause the same type of oscillatory currents as the surge generator capacitors which, as explained, may interfere with the normal functioning of the lightning arrester. Therefore, the capacitor C_2 should be separated from the test piece by a resistance R_2 or by a small reactance L_3. The resistor R_2 must be kept below certain values because of its effect on the recovery voltage.[11] In a surge circuit with negligible reactance, R_1 and R_2 determine the initial voltage available for the spark-over of the test piece. If this is insufficient, additional impedance to the drain of surge energy may be provided by the reactance L_3. It is important, however, that the C_2 L_3 circuit be kept from oscillating, particularly in tests with low power-follow currents because of the possibility of establishing unrealistic current zeros. To eliminate oscillations in the L_3 C_2 loop,

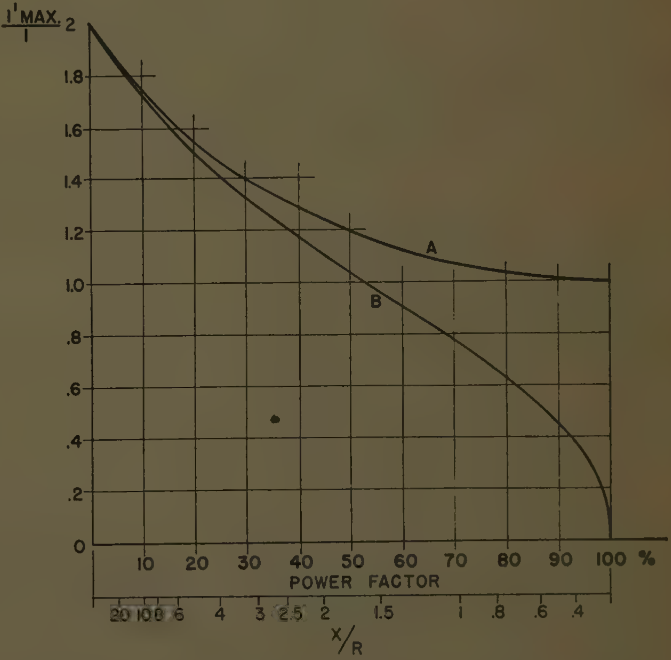

Figure 2. **Ratio of maximum possible peak current to symmetrical crest current as a function of power factor. (A) Symmetrical current remaining constant; peak current equals $\sqrt{2}I_{rms}$ A; (B) Resistance being added to fixed circuit reactance X; peak current equals $(E_{rms}/X)\sqrt{2}$B**

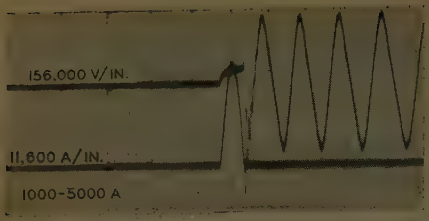

Figure 3(A). Magnetic oscillogram of a line-type expulsion lightning-arrester operation

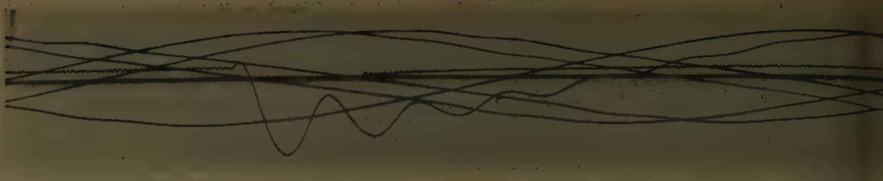

Figure 3(B). Cathode-ray oscillogram of the voltage of same line-type expulsion ligh ning-arrester operation as Figure 3(A)

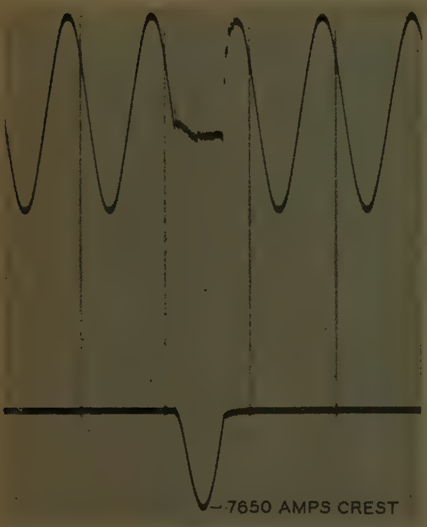

Figure 4. Operation of an expulsion lightning arrester on a 70-per cent power-factor circuit with E/X equal to 7,500 amperes rms; showing a low crest current despite maximum severity timing

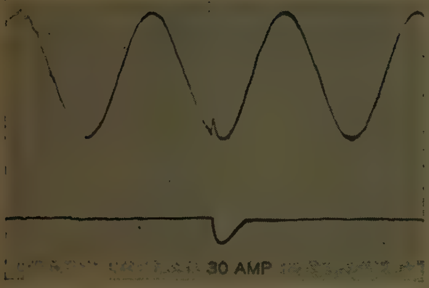

Figure 5. Power follow in a valve-type lightning arrester

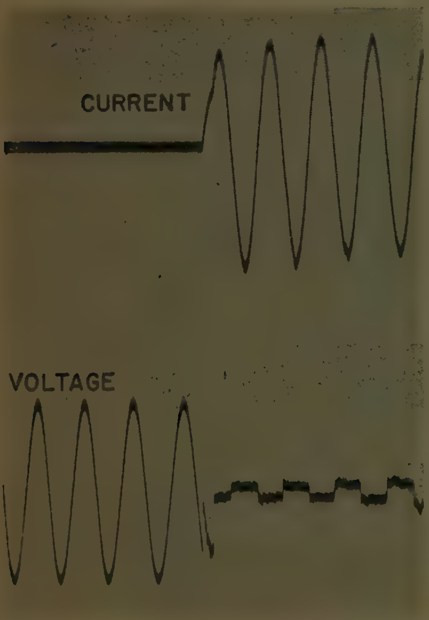

Figure 6. Failure to interrupt power follow of an experimental expulsion lightning arrester

R_2 must be about twice, or R_3 about one-half times $\sqrt{L_3/C}$ if either resistor is used alone.

From the foregoing discussion it is evident that befor power voltage is applied, a certain amount of testing an circuit adjustment is required in order to assure that th test piece sparks over consistently. It occasionally happen that despite these preparations the lightning arreste refuses to operate when the power supply circuit is close in. The cause for this behavior usually is found in th resultant lowering of the total circuit impedance. In thi case the preliminary tests should be made with the primar of the power transformer shorted, or with the power sourc circuit fully connected but de-energized.

In order to evaluate tests properly, it is essential tha voltages and currents be recorded adequately. The location as well as the characteristics of the measuring device must be given proper consideration. The measuremen of the recovery voltage deserve particular attention becaus changes in this quantity sometimes have a decisive influenc on the performance of the protective device. Magneti oscillographs, as well as potential transformers, can b relied upon for faithful recording as long as the measure frequencies are below, and not too close to, either th response limit of the vibrator element or the resonan frequency of the measuring circuit. Oscillations whic can be read clearly on the magnetic record usually ar far enough from these limitations and therefore are reliabl The magnetic and cathode-ray voltage records of Figure 3*A* and *B*, for instance, agree very closely, although th recorded frequency is close to 1,000 cycles. The cathode ray oscillogram is taken over a capacity divider and i recorded on a film drum of 18-inch periphery rotating a 6,000 rpm. As the film is exposed for several revolution of the drum the lines overlap, but they can readily b traced through.

Figure 4 shows the test of a 9-kv expulsion-type lightnin arrester on a circuit whose reactance would permit current of 7,500 amperes rms, but which had a resistanc $R_0=0.83$ ohm added, making the power factor abou 70 per cent. The discharge was initiated by a surg about 10 degrees from voltage zero. The current reache a crest of 7,650 amperes, which makes the crest curren ratio 7,650/7,500×1.41=0.72. Although the effects c arc voltage are not strictly accountable, this is in goo agreement with the value predicted by curve *B* in Figure

Figure 5 shows the power follow in a valve-type lightnin arrester. There is no voltage recovery surge becaus voltage and current go through zero at practically the sam instant. Because of the current-limiting effect of the valv

ent, the follow current is independent of the available
-circuit current.

gure 6 is the record of the failure of an experimental
lsion lightning arrester; the sharp break in arc voltage in
irst half-cycle of power follow indicates clearly that this
the crucial moment and that the integrated effects of
ent and arc voltage up to that point only were respon-
for failure of the device.

ne decisive features in performance tests, however, are
always as plainly evident as on the records cited here.
staking analysis of seemingly insignificant details in
lograms, the appreciation of the functions of the various
ches of test circuits, and the critical inspection of the
piece must be combined to get full value out of test
ts which are a major and quite expensive part of the
neering endeavor in the development and the applica-
of protective devices. Their number has increased
iderably in the last decade or two. With regard to
merits, staged tests cannot furnish unequivocal
vers as long as the range and the effects of the many
ables which influence test performance are not con-
ed sufficiently. A broad analysis of some of these variables, in particular of impulse timing and of the power factor, has been the object of this paper.

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Recording Styli, the Burnishing Facet, and a Process for Resharpening

C. F. STRANDBERG
STUDENT MEMBER AIEE

A simple and inexpensive process for resharpening sapphire, stellite, and steel recording styli has been revealed. The method involves immersing the stylus in a sodium hydroxide solvent instead of regrinding the tool.

ROOF WAS established
late in 1949 that dull re-
cording styli are in most
s not dull at all. The
ctionable noise produced
over 95 per cent of all
aged styli can be re-
ed without regrinding. A unique and inexpensive
e, incorporating a controlled, chemical cleaning proc-
for resharpening all types of recording styli,[1] is now
lable to the recording industry.

ealizing that a process for resharpening by cleaning
tes some of the long-accepted ideas about recording
proof of these violations will be given in this article.

THE STYLUS AND ITS BURNISHING FACET

ADDITION TO the ordinarily visible surfaces of the
andard stylus, a tiny, flat facet is fashioned around
cutting edge of all lacquer-recording styli. This burnishing facet serves the sole purpose of producing a quiet groove.

Before F. L. Capps designed the standard lacquer-recording stylus, a stylus without a burnishing facet was used to cut sound grooves in a wax medium. Owing to the softness of the wax, the feather-edge stylus (a stylus having no burnishing facet) was able to make noise-free engravings. The wax masters produced good fidelity and low distortion, but immediate playback severely damaged the recordings. The wax masters had to be processed and hard pressings made from them. The standard recording stylus, incorporating a single burnishing facet, was designed by Mr. Capps so that sound recordings could be made in lacquer or cellulose acetate, which is sufficiently durable for immediate playback. Today virtually all phonograph records are made from lacquer originals.

Figures 1*A* and 1*B* show back and side views, respectively, of a sapphire stylus. In Figure 1*B*, it is important

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al text of the paper awarded the Best Student Paper Prize for papers presented
the period August 1, 1949, to July 31, 1950.

trandberg is with the Strandberg Engineering Laboratories, Greensboro, N. C.
the paper was written he was a student at Duke University, Durham, N. C.

to note the exceedingly small portion of the entire sapphire that is actually used to cut the groove. A front view reveals the outline of the burnishing edge. The burnishing facet itself can be seen only in lateral aspect (Figure 1*B* inset circle) at the extreme tip of the stylus, where the width of the facet is greatest. Manufacturing methods require that the burnishing facet taper from about one mil at the tip to 0.2 mil at a point corresponding to the top of the groove wall. The burnishing facet is fashioned along the outer edge of the stylus, and no sharp point is met by the facet at the tip. Instead, the tip is circular, having a radius of about 0.2 mil.

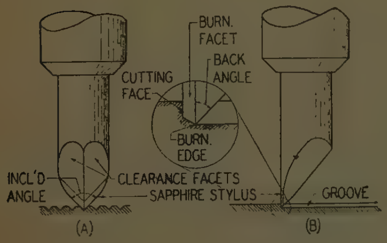


Figure 1. (A) Back and (B) side views of a sapphire stylus

The included angle shown in Figure 1*A* is usually 87 degrees. The importance of this angle, whether the stylus is fitted with a burnishing facet or not, is largely limited to difficulties in pressing for mass manufacture. It has been found experimentally that "horns," shown in Figure 2, become more predominant at smaller included angles.

PURPOSE OF THE BURNISHING FACET

FIGURE 3*A* shows the functional portion or cross section of the stylus in an unmodulated groove. The burnishing facet forms an angle of 25 degrees with each side wall, the leading edge of the facet cutting and the trailing edge burnishing or polishing. This polishing action leaves the groove wall smooth and free of noise.

Under modulated conditions, the stylus is carried on lateral excursions of direction and slope depending upon the magnitude and frequency of the audio signal being recorded. The angular relationship between the burnishing facet and its adjacent groove wall is then under radical change, Figure 3*B*. The 25-degree angle has been selected for optimum burnishing under most amplitude and frequency conditions. It is intended that the groove slope shall never exceed 25 degrees, at which limit the burnishng action ceases to exist, and a state of "tearing" is introduced, Figure 3*C*. This tearing of the modulated groove wall produces noise modulation, which becomes quite troublesome at high frequencies. Recently, an improved stylus having several burnishing facets has been developed which is capable of burnishing under more extreme conditions than is the ordinary standard stylus. In using this new stylus, each burnishing facet of which is considerably more narrow than the standard single facet, a better high-frequency registration was noted.

If a stylus having a small included angle is used, horns are left on the surface. The inside surface of the horns are highly polished and should not be removed. If the
original is plated for purposes of pressing, it is comm
practice to wipe the master with a cloth, giving it a hi
luster. Because the horns are subjected to an unev
wiping pressure, a logical reason for this noise producti
might lie in the possible chipping or partial removal
these horns.

INERTIA EFFECT ON HIGH-FREQUENCY REGISTRATI

WITH A CLEAR understanding of the position a
purpose of the burnishing facet in mind, so
interesting derivations can be made with regard to hig
frequency registration.

One theory involves the effects of high-frequency
tenuation as a function of the stylus weight, the physi
impedance of the recording medium in being displac
laterally, and the characteristic of the magnetic circ
delivering mechanical power to the stylus. The recordi
or cutting head contains the magnetic circuit to wh
audio-frequency power is supplied. The head transf
electric power to mechanical power. The mechani
power then is absorbed in driving the shank of the sty
laterally in accordance with the applied signal.

If the characteristic of the recording head were c
sidered to represent the efficiency of transfer of the elect
power to mechanical power over a specific range of f
quencies, then the magnitude of the load absorbing t
mechanical energy must be taken into considerati
Because faithful lateral motion of the stylus in engrav
the grooves represents the ultimate requirement, t
mechanical load may be considered as that amount
power required to overcome the impedances which
against lateral motion. Such impedances may be rep
sented collectively as inertia.

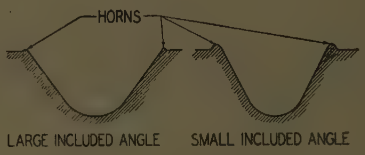


**Figure 2. Larger "hor
are produced by a sty
with a small included an**

The forces of inertia are functions of the stylus wei
and the mechanical stress of the lacquer material act
against the area of the subjected portion of the burnish
facet.

High-frequency attenuation is then proportional to
forces of inertia acting against lateral movement of
stylus. Note that a decrease in the subjected area of
burnishing facet, as a result of reducing its width, w
result in less structural impedance to lateral moveme
less force of inertia, and ultimately, better high-freque
registration.

The reasoning to this point leads one to believe t
better high-frequency registration afforded in systems
recording where smaller dimensions are used is due so
to reduced inertia.

EFFECT OF "PARALLEL DIMENSION"

THE REASONING, however, is far from adequate
conclusive. This article will introduce a new fu

ntal concept of high-frequency attenuation as a function dimension. This concept has no bearing whatsoever inertia, although the total force of inertia is proporal to stylus dimensions.

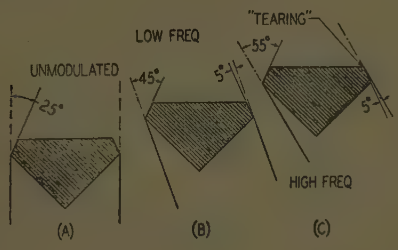
t this point, a definition is needed for an imaginary jection of the burnishing facet width against the groove ls.

igure 3 shows the functional portion or cross section of stylus. Under conditions of no modulation the burnish- facet makes an angle of 25 degrees with each groove l. The maximum groove slope is proportional to the quency of the audio signal.

Considering a case in which the cutting speed is 78.26 n and letting the frequency of the audio signal be equal nfinity, the groove slope, also, is infinity. Under such ditions, the faithful lateral movement of the stylus, in ordance with the audio signal, produces a total lateral ng which is proportional to the peak-to-peak value of applied audio signal. The stylus has not moved, wever, in the direction of cutting during the time rered for the stylus to make one complete excursion or le laterally. Effectively, the stylus is caused to modulate ixed point on the disc. The result is a rectangle of gth (perpendicular to groove axis) proportional to the k-to-peak value of the audio signal and width equal to perpendicular distance from the center of the cutting e to the point of intersection of the clearance facets.

The width of the hypothetical rectangle is, however, ersely proportional to the groove depth. The degree proportionality is a function of the back angle (an angle approximately 45 degrees between the stylus vertical d the line of intersection of the clearance facets).

n order to justify any investigation of the effectiveness this width in distorting the groove shape under real her than hypothetical conditions, the least effective ue of width must be used in the calculations. Because roducing styli never track from the bottom of the groove d always ride well up on the walls, as a result of receiving eral drive from the side walls, this width should be taken the average projected width of the burnishing facet from stylus tip to a point corresponding to the top of the ove wall. The burnishing facet width tapers from about mil to one mil. The average width is 0.6 mil.



ure 3. Relationship ween burnishing le and modulation frequency

The projected width is defined as the quantity "parallel nension"; this parallel dimension equals the average rnishing facet width times the cosine of the burnishing gle.

n a typical case a standard recording stylus having an rage burnishing facet width of 0.6 mil is used to cut a modulated groove in a standard 10-inch disc revolving at 78.26 rpm at a radial distance of two inches in from the outside or three inches from the center. The modulation frequency is 10,000 cycles per second. Then

$$\text{Cutting speed} = \text{turntable speed} \times \text{groove circumference}$$

$$= \frac{78.26}{60} \times 6\pi = 24.55 \text{ inches per second}$$

$$\text{Recorded wave length} = \frac{\text{cutting speed}}{\text{frequency}}$$

$$= \frac{24.55}{10{,}000} = 2.455 \text{ mils}$$

$$\text{Parallel dimension} = \text{Average burnishing facet width} \times \text{cosine of burnishing angle}$$

$$= 0.6 \times \cos 25° = 0.543 \text{ mil}$$

Portion of recorded wave length occupied by parallel dimension

$$= \frac{\text{parallel dimension}}{\text{recorded wavelength}} = \frac{0.543}{2.455} = 22.1 \text{ per cent}$$

This means that at 10,000 cycles per second a parallel stylus dimension is occupying nearly one-fourth of the complete cycle. This causes the maximum lateral groove displacement and the point that should be on the zero axis to coincide, thus heavily attenuating, if not completely obliterating, any registration at that frequency.

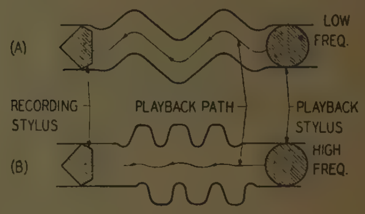


Figure 4. Effect of the facet on the groove

At frequencies considerably higher than 10,000 cycles per second only a wide, slopeless groove will result, permitting the playback stylus to run randomly along it. Such a groove shape is shown in Figure 4*B*. The parallel dimension of the recording stylus cuts away its own engravings after each change of direction. The playback stylus, the cross section of which is circular, is not modulated appreciably by the badly distorted groove. At a somewhat lower modulating frequency, as is shown in Figure 4*A*, registration is satisfactory. In subsequent playback, reproduction is good.

It should be noticed that this attenuating effect varies according to the radial distance of the stylus from the center of the disc.

At 33.33 rpm this reasoning is substantiated by the fact that styli intended for use at that speed must be fitted with a slightly narrower burnishing facet for good performance. Theoretically, turntable speed should have little effect on the forces of inertia, as the stress in the lacquer material is constant, regardless of speed. The development of the Anti-Noise Modulation Stylus (a stylus which has two or more very narrow burnishing facets) and the microgroove method are examples of decreases in parallel dimension, although the purpose was to decrease inertia. In addition, microgroove recordings are usually pre-emphasized in the upper register, as in lateral transcriptions, to provide for easier equalization.

The width of the burnishing facet is, then, proportional to the attenuation of high-frequency registration for an important reason having no bearing on inertia. According to such reasoning, expensive efforts to design and build high-fidelity recording heads are useless when the stylus itself is capable of introducing such distortion. By all means, the attenuating properties of the stylus should be considered for it is not the characteristic of the magnetic circuit delivering mechanical power to the stylus that is important but, rather, the eventual recorded characteristic that is meaningful.

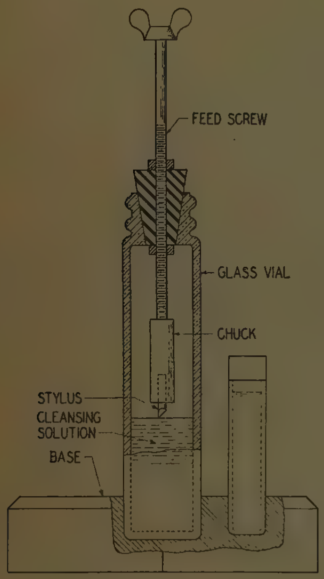


Figure 5. The complete Sapphire Tip Cleansing Instrument for use with a sodium hydroxide solvent

The high-frequency attenuation then may be considered a function of two fundamental quantities in disc recording:

1. The forces of inertia, which act against high-frequency lateral movement of the stylus while cutting.
2. The burnishing facet width, which acts as a parallel dimension, capable of serious attenuation and eventual obliteration at wavelengths sufficiently short such that the parallel dimension is appreciable with respect to the wavelength.

PROCESS AND APPARATUS

THE PRODUCTION of noise transients in disc recording is apparently associated very closely with the proper performance of the burnishing facet in polishing the groove walls. Resharpening by grinding is considered necessary when a stylus produces surface noise. This noise production is considered a result of a dull stylus.

Damages to recording styli occur frequently. Very often the stylus is caused to cut through the lacquer material and make momentary contact with the aluminum base supporting the lacquer coating. Such contact produces a highly audible hiss, and the result is a defective stylus. The hiss continues throughout the recording process and is reproduced in the form of objectionable noise during subsequent playback.

There are many causes for stylus damages. U observed warps or other defects in the disc contribu heavily to such troubles. Entanglement of the chip (t displaced recording material in the form of a threa around the stylus often causes the downward pressure be increased sufficiently so that momentary contact made with the metal base. Care must be exercised lowering the recording head and stylus to the revolvi surface, as damages are frequently encountered in th initial operation.

An investigation was made of defective sapphire recor ing styli. Sapphire, Al_2O_3, is a stone having a hardne which approaches that of a diamond. It is not easily dull or worn, particularly by aluminum, one of the softe metals. It was found that when a contact occurs betwe the stylus and the metal base a high surface noise is usua introduced, not because the sapphire is dulled by t aluminum but because the sapphire collects tiny pieces aluminum. These microscopic particles usually cli to the cutting face in the vicinity of the cutting edg Provided that the tiny particles do not extend in a later or downward direction far enough to produce a shado over any part of the burnishing facet, no objectiona noise will result. In the great majority of observed case however, the microscopic aluminum particles extend o this critical facet, rendering it ineffective in polishing t groove wall.

A simple and unique device has been developed f cleaning sapphire, stellite, and steel styli, the trade name which is Sapphire Tip Cleansing Instrument.[1] T apparatus is designed for use with a sodium hydroxi solvent, and the complete device is shown in Figure The feed screw assembly holding the stylus chuck is lower only until adhesion occurs between the tip and the solutio Because the chemical concentration used is only 4 per ce little danger of exposing the metal shanks of the styli the solvent exists, and only slight capillary action c occur in the time of five minutes required for comple resharpening.

Comprehensive tests were made to determine just ho effective such a process for resharpening is. It was fou that over 95 per cent of all defective styli damages cou be repaired completely. The remaining 5 per cent we either broken through misuse or had been slightly chipp in recording on defective blanks.

CONCLUSIONS

UNDERSTANDING the nature of the fundamental quantit affecting high-frequency registration and reproducti might easily be the key to the development of extreme wide-band recording, such as would be needed for sup sonic and possibly video recording.

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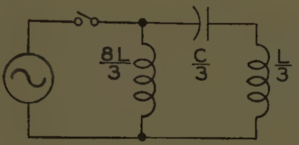
Electrical Essay

A Distortion Network

: the end of his talk on Heaviside's operators in enginǝing and physics in which he introduced the unit func- the time differentiator p, the "resistance operators" the circuit constants, and the operational forms of soidal functions of time, the engineer from the land of electrical constants invited his listeners to submit their vork problems to him and he then would solve them as lustration of his talk. One of the problems submitted the floor may be called a distortion network and may escribed as follows:

2-branch parallel circuit has a $C/3$ farad capacitor nected in series with an $L/3$ henry inductor in one of its



re 1. **A distortion network**

nches, and an $8L/3$ henry inductor in its other branch. network is illustrated in Figure 1. It is connected to a ce of sinusoidal voltage of a frequency defined by $\omega=$ $\sqrt{LC}$. The switch connecting the network to the age source is accurately controlled to close and open on crest of the voltage wave.

he engineer proceeds with the reduction of the network edance to an operational form. Making $R=(8/9)$ $\overline{L/C})$ he obtains the following operational impedance:

$$=R\frac{p(p^2+9\omega^2)}{3\omega(p^2+\omega^2)} \qquad (1)$$

enoting by E the crest value of the voltage wave and ng into account the stipulation of controlled switching, engineer expresses the impressed voltage as follows:

$$\frac{p^2}{p^2+\omega^2}1 \qquad (2)$$

Vhat currents will the network and its two branches w when the switch is closed and when it is opened?

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Answers to Previous Essays

Ballast. The following is the author's answer to his viously published essay (*EE, Apr '51, p 351*).

'he capacitor connected in parallel with the load for ver-factor correction must be rated as follows:

sin θ(base)kva; $x_1=\frac{z^2}{x}$ ohm; $b_1=b$ mho

The reactor and capacitor x_2 are resonant at the system frequency and must both be rated as follows:

$$Q_2=\frac{\cos\theta}{\sqrt{3}}\text{ (base)kva;}\quad x_2=\sqrt{3}\frac{z^2}{r}\text{ ohm;}\quad b_2=\frac{g}{\sqrt{3}}\text{ mho}$$

Denoting by R the value of z^2/r (or $1/g$), the phase-A sequence components of line-to-neutral voltages and of line currents are related by the following:

$$E_0=RI_0+2RI_1$$
$$E_1=RI_1+2RI_2$$
$$E_2=RI_2+2RI_0$$

The impressed values are E_1, E_2, and I_0.

E_1 = line-to-neutral voltage of line
$E_2=0$
$I_0=0$

The derived quantities then are:

$E_0=2E_1$
$I_1=E_1/R$
$I_2=0$

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Seven Networks. The following is the author's answer to his previously published essay (*EE, Apr '51, pp 351–52*),

In accordance with Heaviside's rules, the inductors and capacitors are replaced with their "resistance operators" Rp/ω_0 and $R\omega_0/p$. Here $R=\sqrt{L/C}$, $\omega_0=1/\sqrt{LC}$, and p, the time differentiator, all follow the laws of ordinary algebra. Thus the three branches of the network of Figure 2 from left to right are expressed by the following "resistance operators:"

$$R_1=R\frac{p^2+3\omega_0p+\omega_0^2}{\omega_0p+\omega_0^2}$$

$$R_2=R\frac{p^2+3\omega_0p+\omega_0^2}{\omega_0p}$$

$$R_3=R\frac{p^2+3\omega_0p+\omega_0^2}{p^2+\omega_0p}$$

But

$$\frac{1}{R_0}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

And

$$R_0=R$$

Similarly, each network of Figure 1 reduces to the same "resistance operator" $R_0=R$. So, all seven networks assembled by the engineer are general equivalence networks.

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Motionally Induced Electric Fields—Part VI. The following is the author's answer to his previously published essay (*EE, Apr '51, pp 350–51*).

Question 1. No, this resolving of the magnetic field into variously moving component fields is without verifiable physical meaning and in many cases will lead to absurdities, as the next two essays will show. As was said in the preceding author's reply (*EE, Apr '51, pp 352–53*), the electric and magnetic fields in Maxwell's equations are vector fields, and nothing more; for each field, at each point of space, a direction and a magnitude, and that is all.

If in a given region we know these vector fields, we know all. We do not need to go ranging over the universe to see where our magnetic field "comes from" or "originates" to be enabled to determine what happens when a local metal body moves in a locally completely observable magnetic field.

In general, a set of differential equations like Maxwell's, including the constitutive equations, has infinitely many solutions, in spite of the fact that the number of independent equations is equal to the number of independent unknowns. To determine a solution uniquely we need what are called boundary conditions. For a local region such as that in which our metal slide bar is moving, it is enough to know the electromagnetic field vectors throughout the region at one instant of time, and to know for a sufficient time earlier, and for subsequent time, the values of the electromagnetic vectors on a closed surface enclosing the region. The fact that such boundary conditions are sufficient for fixing the solution to Maxwell's equations is the whole meaning of the statement that Maxwell theory is a "local action" theory.

Now, in our case, what happens to the metal slide bar is completely determinable from the field vectors observed over an enclosing surface surrounding the conductor and inside the iron tube. These field vectors may be determined by direct observation of the forces on momentarily stationary or moving probe charges, or we may calculate them by the method described in the author's reply Part IV of the series (*EE, Mar '51, pp 255–56*). We fin of course, that there is a much reduced magnetic field but also there is an electric field **E** observable by the for on a charged probe momentarily at rest, in the emp space inside the iron tube, and outside also, with

$$\mathbf{E}+\frac{1}{c}\,[\mathbf{v}\times\mathbf{B}]=\frac{1}{c}[\mathbf{v}\times\mathbf{B}_0]$$

Is this field **E** a motional field, or is it induced by varyi magnetic fields? That is a meaningless question.

Now, since the constitutive equation for the metal b inside the iron tube is

$$\mathbf{i}=\sigma\left(\mathbf{E}+\frac{1}{c}[\mathbf{v}\times\mathbf{B}]\right)$$

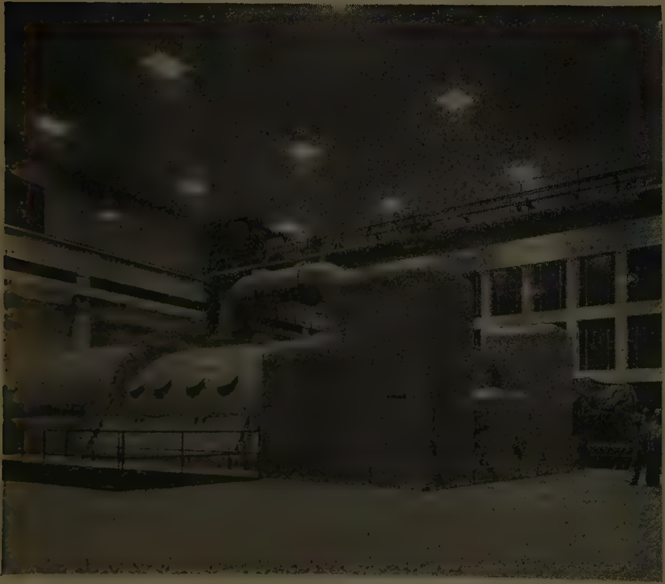
we see by equation 1 that the flow of current in it is the sa as if the bar were not inside the iron tube but was movi in the uniform magnetic field $\mathbf{B}_0$ and with the electric fie **E** equal to zero. We do not need Jack's device of r quiring the weak field **B** to "really" be a "stationar field $\mathbf{B}_0$, with a nearly equal and opposite field, $\mathbf{B}-$ "moving" with velocity **v**. There is no place in Maxwel equations for a field velocity **v**. The place for **v** is in t constitutive equations for material moving with veloci **v**. Macroscopic material has the property of recognizab continuing individuality, so that for it the velocity **v** h meaning

Question 2. As the author's reply to question 1 is bit long, the author asks the reader's indulgence in pos poning the discussion of question 2 to the next issue *Electrical Engineering*.

J. SLEPIAN (F

(Westinghouse Research Laboratories, East Pittsburgh, P

Detroit Edison Puts New Steam Turbogenerator Into Operation



Southwestern Michigan's electric power supply was i creased 135,000 horsepower recently with the starting up a new steam turbogenerator at Detroit Edison's Conne Creek power plant. The 100,000-kw machine produc enough electricity to supply a city of 215,000 people. Th turbogenerator cost approximately $15,000,000 and is th first of two identical units being installed at Conners Cree The second will go into operation in September. Both we built by the Westinghouse Electric Corporation. The ne generating unit weighs more than 800 tons. Steam ente the turbine at 950 degrees Fahrenheit and at a pressure 1,300 pounds. The boilers can generate 600,000 pounds steam per hour. The condenser requires 74,000 gallo per minute of cooling water, which is pumped direct from the Detroit River and then returned, purified, to th river. Addition of the Conners Creek generator is o step in an expansion program that will bring Detroit Ed son's total power capacity to 3,000,000 horsepower by 195

NSTITUTE ACTIVITIES

pplication of Fundamental Theory is Theme of Great Lakes District Meeting

e AIEE Great Lakes District Meeting held at the Hotel Loraine in Madison, May 17 through 19, 1951, has as its e "Application of Fundamental ry" and is designed to appeal to all elec- l engineers regardless of specialization. ery effort is being made to include Stu- Members of the AIEE in all activities to it maximum contact with practicing neers. Students may go to the regular neons and banquet, may take the in- ion trips, and attend the sessions. Spe- graduate and undergraduate sessions will eld on Friday and Saturday morning. ents' wives are invited to attend all the tions arranged for the ladies.

addition to the technical sessions, there be luncheons, a banquet, a Student ban- , a special ladies' program, and inspec- trips.

All technical sessions, including the Student sessions, will be held at the Loraine Hotel. The Student Chairmen and Faculty Counselors meeting will be held Saturday, May 19, at 9:00 a.m. in Room 2033, Electrical Engineering and Mechanics Building, University of Wisconsin. Luncheons, except the Ladies' Luncheons, will be held at the headquarters hotel (Loraine). The regular and Student banquets will be held at the Memorial Union on the University of Wisconsin campus.

ADVANCE REGISTRATION

Please register in advance by promptly filling in and mailing the advance registration card enclosed with the mailed announcement. Registration should be completed at the Registration Desk on arrival at the meeting. The Registration Desk will be open beginning the evening of May 16. A registration fee of $2 will be charged all members and $3 for all nonmembers. No fee will be required of enrolled Students or the immediate families of members.

INSPECTION TRIPS

Forest Products Laboratory. Thursday, May 17, 2:00 P. M., or Friday, May 18, 2:00 P. M. This is a United States Department of Agriculture research laboratory that directs its work toward increasing knowledge about wood and wood products. A great deal of work has been done at this laboratory on wood strengths, preservation and utilization; on paper, packaging, laminating, and wood fabrication.

Electrical Engineering and Mechanics Building. Thursday, May 17, 2:00 P. M., or Friday, May 18, 10:00 A. M. or 2:00 P. M. This is a new building which has been occupied less than one year and contains all laboratories and classrooms of the electrical engineering and mechanics departments. The laboratories, educational facilities, and materials used in construction are most modern.

Veterans Hospital. Friday, May 18, 10:00 A. M. This is a $7,000,000 nearly completed 500-bed hospital, built on a 23-acre tract overlooking Lake Mendota, containing 8 floors and penthouse. The connected electric load will be 18,000 kva and 1,200 lighting fixtures and 550,000 feet of wire will be used in the building. It contains the latest in interior wiring materials.

Utilities Tour. Inspections at convenience of those wishing to visit plants. The city of Madison is supplied with electricity and natural gas by the Madison Gas and Electric Company. Electricity is generated by a local steam plant having a capacity of 70,000 kw. The Wisconsin Power and Light Company has offices in Madison and furnishes electricity to central and southern Wisconsin. One of their newest steam plants with two 25,000-kw units installed is at Beloit. The unique feature of this plant is that the steam- and electric-generating equipment are not separated by any of the building structure.

In addition to these inspection trips, the ladies will take a tour of the University of Wisconsin and the Arboretum. There are many points of interest in Madison such as the University of Wisconsin, Capitol, machine tool industry, and scenic drives which those attending the meeting may wish to see. Members desiring to see any points of interest should inform the Registration Desk and arrangements will be made to show them whatever they wish to see.

GENERAL INFORMATION

Detailed information may be obtained at the Registration Desk, and the bulletin board

(*Continued on page 455*)

Future AIEE Meetings

h Eastern District Meeting
el Syracuse, Syracuse, N. Y.
2–4, 1951
al date for submitting papers—closed)

E Conference on Domestic Appliances
age 457)
elle Memorial Institute, Columbus, Ohio
15, 1951

at Lakes District Meeting (*page 453*)
ine Hotel, Madison, Wis.
17–19, 1951
al date for submitting papers—closed)

mer General Meeting (*page 455*)
al York Hotel, Toronto, Ontario, Canada
25–29, 1951
al date for submitting papers—closed)

fic General Meeting
tnomah Hotel, Portland, Oreg.
ust 20–23, 1951
al date for submitting papers—May 21)

E Conference on Aircraft Equipment
Angeles, Calif.
ober 8–10, 1951

E Conference on Fractional Horse- er and Motor Applications to Re- eration Equipment and Pumps
ton, Ohio
ober 11–12, 1951

General Meeting
el Cleveland, Cleveland, Ohio
ober 22–26, 1951
al date for submitting papers—June 22)

ter General Meeting
el Statler, New York, N. Y.
uary 21–25, 1952
al date for submitting papers—October 23)

Photograph courtesy of Calberne Aerial, DePere, Wis.

This is an aerial view of central Madison, where the AIEE Great Lakes District Meeting will be held May 17–19. The headquarters hotel is at the right of the photograph

Tentative Technical Program

Great Lakes District Meeting, Madison, Wis., May 17-19

Thursday, May 17

9:00 a.m. Registration

10:00 a.m. Opening Session

J. R. North, presiding

Official Welcome. Honorable Walter J. Kohler, Governor of Wisconsin

New Problems of the Institute. Titus G. LeClair, President, American Institute of Electrical Engineers

Corona Effects on Transmission Lines. C. F. Wagner, Westinghouse Electric Corporation

2:00 p.m. Generating Stations Equipments

J. P. Madgett, Jr., presiding

51-157. An Engineering Approach to Control Room Lighting. *V. L. Dzwonczyk*, American Gas and Electric Service Corporation

DP. Control System of the New 60,000 K.W. Edgewater Generating Station of the Wisconsin Power and Light Company.** *G. Schilstra*, Wisconsin Power and Light Company

DP. Unique Induction Generator Hydro Plant.** *H. H. Brown*, Wisconsin Michigan Power Company

51-158—ACO.* Squirrel Cage Induction Generator for Power Generation. *T. C. Tsao*, Consolidated Edison Company of N. Y., Inc.; *N. F. Tsang*, University of Minnesota

2:00 p.m. Induction Motors

S. Beckwith, Presiding

51-159. A Contribution to the Theory of the Deep-bar Induction Motor. *J. F. H. Douglas*, Marquette University

51-160. Split-Winding Starting of Three-Phase Motors. *P. L. Alger, H. C. Ward, Jr., F. H. Wright*, General Electric Company

DP. Performance Characteristics of the Doubly-Fed Induction Machine.** *G. W. Staats*, Allis-Chalmers Manufacturing Company

DP. Application of Thevenin's Theorem in Induction Motor Theory.** *B. S. Willis*, Iowa State College

2:00 p.m. Communication Circuits

V. C. Rideout, presiding

DP. Non-linear Element Applications to T and π Networks.** *C. J. O'Connor, G. W. Valenta, H. E. Ellithorn*, University of Notre Dame

DP. Characteristics of Twin-T and Bridged-T Networks.** *J. L. Poteracke, M. V. Braunagel, H. E. Ellithorn*, University of Notre Dame

DP. The Realization of a Transfer Ratio with Complex Zeros in the Form of a Three-Terminal R-C Network.** *P. F. Ordung, G. S. Axelby, H. L. Krauss, W. P. Yetter*, Yale University

DP. Determination of the Resistance of a Homogeneous Screen of Linear Conductors.** *J. P. Ballantine*, University of Washington

51-161—ACO.* Hum and Stability Problems of Power Line Synchronization in Television. *W. L. Hughes*, Iowa State College

2:00 p.m. Unique Field Mapping Procedures

L. C. Larson, presiding

DP. A Direct-Current Network Analyzer for Wave-Equation and Field-Mapping Problems.** *G. W. Swenson, Jr.*, University of Wisconsin

DP. The Use of the Electrolytic Tank in Investigating Heat Flow Inside Magnet Coils.** *J. D. Horgan*, Marquette University

51-162. Mapping Techniques Applied to Fluid Mapper Patterns. *A. D. Moore*, University of Michigan

2:00 p.m. Servomechanisms

N. L. Schmitz, presiding

DP. Multiple Mode Operation of Servomechanisms.** *D. C. McDonald*, Cook Research Laboratories

DP. Transient Response of Two-Phase Induction Motor Type Servomotor.** *K. Fong*, University of Illinois

51-163. Transient Response of Small, Two-Phase Induction Motors. *A. M. Hopkin*, Northwestern University

DP. Transfer Function for a 2-Phase Induction Servo Motor.** *L. O. Brown, Jr.*, University of Illinois

Friday, May 18

8:30 a.m. Undergraduate Student Technical Papers

9:30 a.m. Transmission and Distribution

E. J. Kallevang, presiding

DP. Design Features of a New 138 Kv Transmission Line.** *F. Linder*, Dairyland Power Cooperative

DP. Analysis of Subsequent Faults.** *H. K. Amchin*, American Gas and Electric Service Corporation; *E. T. B. Gross*, Illinois Institute of Technology

DP. Symmetrical Components as Applied to Protective Relaying.** *W. K. Sonnemann*, Westinghouse Electric Corporation

DP. Low Cost Regulation of Rural Distribution Lines.** *H. C. Brem*, Allis-Chalmers Manufacturing Company

DP. Three-Phase Dielectric Power-Factor Me urements on Cables.** *L. W. Matsch*, Illinois Instit of Technology

51-165. Effect of the Duration of Voltage Dip Cyclic Light Flicker. *L. Brieger*, Consolidated Edi Company of N. Y., Inc. Presentation by title o for discussion

9:30 a.m. Industrial Electronics

R. R. Benedict, presiding

51-166. Ignitrons for Frequency-Changer Welde *R. R. Rottier*, Westinghouse Electric Corporation

51-167. Ignitron Rectifier Power for Dynamomete *E. L. Hulla, T. H. McGreer, J. W. Strumpfer*, Westi house Electric Corporation; *E. G. Morehouse*, Studeba Corporation

51-168. A Gas Tube Inverter with the Supp Voltage Below the Breakdown Voltage. *J. M. C J. C. Schuder*, Purdue University

51-169. Correlation of Temperature and Elect Fields in a Material Undergoing Dielectric Heati *T. J. Dunsheath*, Magnaflux Corporation; *J. A. Lyon*, Northwestern University

9:30 a.m. Computing Devices and Tec niques

J. F. Calvert, presiding

51-170. A Diode Bridge Limiter for Use with El tronic Analog Computers. *R. J. Medkeff*, Aska Regulator Company; *R. J. Parent*, University of W consin

51-171—ACO.* Analog Computer Solution of Nonlinear Differential Equation. *H. G. Markey, V. Rideout*, University of Wisconsin

51-172. Differential Analyzer Study of Harmo Power Generation with Nonlinear Impedance F ment. *P. E. Russell, H. A. Peterson*, University of W consin

DP. An Integrally Synchronized, General P pose Magnetic Drum Digital Computer.** *G. M. dahl*, University of Wisconsin

9:30 a.m. Basic Sciences

W. Richter, presiding

51-173. Dependence of Direct Sparkover Volta of Gaps on Humidity and Time. *P. B. Jacob*, Mississippi State College; *G. M. L. Sommerman*, Nor western University

51-174. Calculation of the Capacitance of a Circu Annulus by the Method of Subareas. *T. J. Higg D. K. Reitan*, The University of Wisconsin

DP. The Magnetic Cross Valve.** *H. J. McCre* Automatic Electric Company

DP. Magnetic Amplifier Analysis Using Fl Charge Theory.** *P. M. Kintner*, University of Illin

DP. Change of Units and Conversion Formu** *V. P. Hessler*, University of Illinois

DP. Electric and Magnetic Units and Dimensic** *G. R. Town*, Iowa State College

51-175. The Transient Response of Magnetic plifiers—Cases of Negligible Commutation. *L. Finzi, D. P. Chandler*, Carnegie Institute of Technolo *D. C. Beaumariage*, Bethpage, Long Island. Presenta by title only for discussion

9:30 a.m. Feedback Control Devices

L. A. Hesse, presiding

DP. Compensated Synchronous Alternator.** *Storm*, General Electric Company

DP. The Measurement and Control of Mois in Textile Slashing.** *C. V. Bullen, R. E. Schuette*, Bar Colman Company

DP. Progress on a Unified Terminology for F back Control System.** *H. W. Cory*, Allis-Chal Manufacturing Company

DP. Ignorable Quantities in Feedback trollers.** *R. W. Jones*, Northwestern University

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—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

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* ACO: Advance copies only available; not intended for publication in *Transactions*.

** DP: District paper; no advance copies are available; not intended for publication in *Transactions*.

p.m. Undergraduate Student Technical Papers

p.m. Graduate Student Technical Papers

p.m. Electrical Machinery

Lewis, presiding

6. **Transient Analysis of Rotating Machines Stationary Networks by Means of Rotating ence Frames.** *Y. H. Ku*, Massachusetts Institute chnology

7. **A Design Method for Polyphase Reluctance ronous Motors.** *C. H. Crouse*, Robbins and Myers,

* **Effects of Unbalanced Loading in a Core Transformer.** *C. V. Mueller*, Purdue University

* **Fundamentals and Applications of Eddy-ent Power Devices.** *G. H. Fredrick*, Dynamatic oration

* **Self Starting, Self Compensating Synchronous r.** *K. L. Hansen*, Milwaukee, Wis.

8. **Improved Core Form Transformer Winding.** *Grimmer*, *W. L. Teague*, Westinghouse Electric Corporation. Presentation by title only for discussion

2:00 p.m. Electrical Measurements

R. E. Johnson, presiding

DP. The Three Phase Oscilloscope as an Harmonic Analyzer in Power Systems.** *E. B. Kurtz*, *R. H. Burkhardt*, State University of Iowa

51-179—ACO.* A Complex Wave Synthesizer. *G. Ferrara*, *R. L. Nadeau*, University of Detroit

51-180. Piezoelectric Crystals as Sensing Elements of Pressure, Temperature and Humidity. *E. A. Roberts*, *P. Goldsmith*, Armour Research Foundation

DP. A Wave Generator for the Dynamic Plot of Receiving Tube Characteristics.** *J. E. Yule*, Marquette University; *G. Koehler*, University of Wisconsin

DP. Surface Temperatures and Heat Transfer Rates of Electrically Heated Wires.** *E. A. Farber*, University of Wisconsin

2:00 p.m. Waveguides and Particle Accelerators

A. Bronwell, presiding

DP. Proton Dynamics in a Linear Accelerator.** *B. V. Haxby*, *H. A. Miller*, University of Minnesota

51-181—ACO.* A Variable Frequency Excitation System for a 70 MEV Synchrotron. *J. D. Ryder*, Universtiy of Illinois; *J. P. Palmer*, Oak Ridge National Laboratory

51-182. Shielded Dielectric-Rod Waveguides. *R. E. Beam*, *H. M. Wachowski*, Northwestern University

51-164. Dielectric Loading for Waveguide Linear Accelerators. *G. I. Cohn*, *G. T. Flesher*, Illinois Institute of Technology

DP. Acoustic Boundary—Layer Losses in Waveguide.** *R. F. Lambert*, University of Minnesota

2:00 p.m. Symposium on Nonlinear Electric Circuit Analysis

T. J. Higgins, presiding

DP. Almost Sinusoidal Oscillations in Systems with Several Degrees of Freedom.** *H. S. Schaffner*, University of Illinois

DP. Current Practices of Solving Nonlinear Problems Arising in Industry.** *E. J. Keller*, General Electric Company

DP. Reliable Nonlinear Networks.** *R. J. Duffin*, Carnegie Institute of Technology

DP. The Stability Theorem of Liapounoff—Its Applications.** *F. E. Bothwell*, Northwestern University

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(*Continued from page 453*)

the desk will contain notices concerning meeting and other events. Please consult equently.

SOCIAL CALENDAR

rsday, May 17

0 noon Luncheon, Loraine Hotel

5 p.m. Ladies' Luncheon, Memorial Union

p.m. Ladies' tour of Madison, University of onsin, and Arboretum

p.m. Banquet—informal. For registrants, guests, , and students. Memorial Union

lay, May 18

0 noon Luncheon, Loraine Hotel

p.m. Ladies' Luncheon, Style Show, and Bridge. chester's Madison Room

p.m. Student Banquet, Memorial Union. Ad- Edwin W. Seeger, Vice-President in Charge evelopment, Cutler-Hammer, Inc.

HOTEL RESERVATIONS

lembers planning to attend the Great es District Meeting are urged to make l reservations now, or as early as possible e sure of accommodations.

Ir. E. J. Kallevang, chief engineer, Wisin Power and Light Company, 122 West hington Avenue, Madison 1, Wis., asks a copy of your request for reservations be to him. Please mention that you are nding the AIEE meeting when you make reservation.

oom rate schedules for four hotels in lison are:

ine Hotel (headquarters) West Washington Avenue		
e rooms	$ 4.00 to	$ 6.00
le rooms	8.00 to	10.00
water Hotel, 666 Wisconsin Avenue		
e rooms	6.00 to	10.00
le rooms	10.00	
	12.00	
Hotel, 22 South Carroll Street		
e rooms	3.50 to	5.00
le rooms	5.00 to	9.00
's Belmont Hotel, 31 North Pinckney Street		
e rooms	3.50 to	5.00
le rooms	5.00 to	8.00

Staff at work in the Electrical Standards Laboratory in the new Engineering Building at the University of Wisconsin, to be visited during the Great Lakes District Meeting

Accommodations at motor courts are available. Early reservations are necessary. Rates at motor courts are approximately $4.00 for single and $5.50 for double occupancy. Three motor courts which are close to Madison are:

Hamacher Motel (On State Trunk Highway 12, 13, and 14), 5101 University Avenue, Madison, Wis.

Mid-View Apartment Motel (State Trunk Highway 12 and 13), Middleton, Wis.

Blue Spruce Motel (On State Trunk Highway 12 and 18), 1901 East Broadway, Madison, Wis.

DISTRICT MEETING COMMITTEE

The officers of the District Meeting Committee are: Carl C. Crane, *Chairman;* Harold A. Peterson, *Vice-Chairman;* W. T. Stephens, *Secretary;* and J. R. Hafstrom, *Treasurer.*

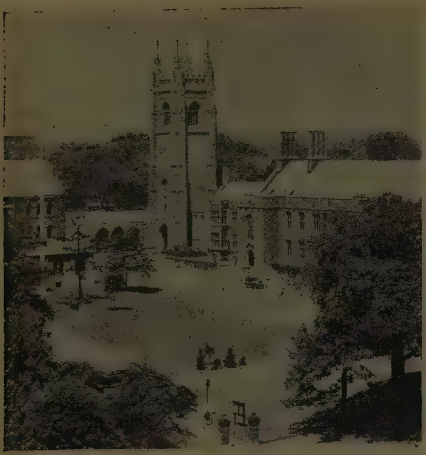
The members of the General Committee are: H. Cole, C. D. Malloch, I. B. Baccus, A. H. Lovell, C. E. Parks, D. D. Ewing, Eric T. B. Gross, J. F. Calbert, J. D. Ryder, M. S. Coover, H. S. Dixon, H. E. Hartig, J. F. H. Douglas, and W. Richter.

The Local Committee Chairmen are: *Technical Program,* T. J. Higgins; *Inspection Trips,* L. A. Hesse; *Entertainment and Sports,* G. Ansel; *Transportation,* F. D. Mackie; *Publicity,* R. E. Purucker; *Finance,* G. C. Neff; *Registration and Housing,* E. J. Kallevang; *Ladies' Activities,* Mrs. W. T. Stephens; and *Student Activities,* Dr. John Baird.

Diversified Technical Program Planned for Summer General Meeting in Toronto

A well-organized and informative technical program is being planned for the Summer General Meeting to be held from June 25 through June 29 in Toronto, Ontario, Canada. A wide variety of subjects will be covered. Among the many papers received are two from members in the United Kingdom.

At the present time Toronto is the engineering center of a major program of expansion in the generation and transmission of electric power now being carried out in the Province of Ontario. This expansion program embraces a number of new central stations, both hydro- and steam-powered.



An evening of entertainment and dancing is scheduled for those attending the Summer General Meeting in Toronto, Canada. This will be held at Hart House, the beautiful student recreational center at the University of Toronto

Because of this, much of interest will be available to visitors to this Province which has a per-capita kilowatt consumption 30 per cent greater than that of the United States of America.

ENTERTAINMENT

The Entertainment Committee reports that a reception will be held by the Lieutenant-Governor of the Province of Ontario, the Honorable Ray Lawson, and that the President's Reception, to be held Monday, June 25, at the Royal York Hotel (headquarters hotel), will take the form of a Buffet Supper and Informal Dance. A novel feature arranged by this Committee will be the Afternoon Tea to be held at the Royal York Hotel, Sunday, June 24, for the entertainment of members and guests arriving early. The program of the social evening planned at Hart House, magnificent student recreational center at the University of Toronto, will include a carillon concert from the carillon located in the Soldier's Tower, a memorial Tower to the students of the University of Toronto killed during World Wars I and II. There will be dancing in three locations, as well as a floor show and an aquatic display in the swimming pool. During the evening a visit will be made to the various parts of this beautiful building and the magnificent quadrangle which will be floodlit for the occasion.

TRAVEL ARRANGEMENTS

Arrangements have been completed with Trans Canada Airlines to allow a 10-per cent deduction for ten or more passengers originating at the same point of departure. Trans Canada Airlines also is arranging a special sight-seeing flight over Toronto and Niagara Falls. Those wishing to take advantage of this interesting feature will be able to make final arrangements on arrival at the Royal York Hotel.

Members should be sure to declare camera equipment, slides or slide films, and samples or other apparatus being brought into Canada for the purpose of demonstrations during the Meeting to the United States Customs Officials at the Border crossing point. This is important in order to facilitate the re-entry of this material into the United States.

HOTEL ACCOMMODATIONS

Rooms have been set aside at the Roy York and King Edward Hotels for t convenience of the members attendi Applications for reservations should be ma directly to the hotel of choice.

Room rates for these two hotels are as f lows:

Royal York Hotel (Meeting Headquarters)	**Rates Per Per**
Single room	$ 6.50 to $ 8
Parlour-bedroom	9.50 to 10
Double room	5.25 to 6
Parlour-bedroom	6.75 to 7
	Rates Per Su
Suites—single occupancy—bedroom and sitting-room	16.00 to 26
Suites—double occupancy—bedroom and sitting-room	20.00 to 31
King Edward Hotel	
Single room, bath (1 person)	5.00 to
Double room, double bed, bath (2 persons)	8.50 to 10
Double room, twin beds, bath (2 persons)	9.00 to 10
Two connecting rooms (3 persons)	13.50 to 16
Two-room suites—single occupancy	12.00 to 15
Two-room suites—double occupancy	15.00 to 18
Three-room suites—single occupancy	18.00 to 36
Three-room suites—double occupancy	24.00 to 36

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in Toronto, Ontario, Canada, at 10:00 a.m., Monday, June 25, 1951, during the Summer General Meeting.

At this meeting the annual report of the Board of Directors and the reports of the Committee of Tellers on the ballots cast for the election of officers and for the proposed amendments to the AIEE Constitution will be presented. The Lamme Medal will be presented to Donald I. Bohn (A '23, M '41, F '49).

Such other business, if any, as properly may come before the annual meeting may be considered.

Signed H. H. HENLINE
Secretary

Honor Five with Fellowship Certificates at Pittsburgh Section Annual Meeting

At its Annual Dinner Meeting on February 26, the Pittsburgh Section of AIEE bestowed the grade of Fellow on five Pittsburgh engineers. The meeting was sponsored jointly by AIEE and the Electrical Section of the Engineers' Society of Western Pennsylvania, and was held at the Schenley Hotel in Pittsburgh.

Cyril G. Veinott, Vice-President of District 2, presented Fellow certificates to: J. Stanley Brown, electrical station engineer, Duquesne Light Company; Clarence A. Atwell, design engineer, Westinghouse Electric Corporation; Royal C. Bergvall, engineering manager, Industrial Products, Westinghouse Electric Corporation; A. A. Johnson, manager, Central Station Engineering, Westinghouse Electric Corporation; and Clarence Lynn, engineering manager, Atomic Power Division, Westinghouse Electric Corporation.

The Pittsburgh Section believes that this method of presentation provides recognition which is richly deserved, and other sections may wish to follow this practice.

In presenting the Fellow Certificates, Mr. Veinott pointed out that only two per cent of the members of the Institute are eligible for the grade of Fellow, the highest grade offered. To be eligible, an engineer must have been an Associate of the Institute for six years, a Member for an additional five years, and be sponsored by five Fellows. Fellows are chosen for their training, experience, and efficiency; for notable and original work in the field of electricity; and for their ability to assume responsibility for work considered highly important by the Board of Examiners and the Board of Directors of the Institute.

Mr. Brown has had wide experience as an electrical designer and engineer for power companies throughout the country. He joined Duquesne Light Company in 1937, and was placed in charge of all electrical engineering, electrical design, and procu ment of materials for power station constr tion. His principal work has been the desi and installation of two 60,000-kw generat at the James H. Reed power station; 65,000-kw generator for the new Frank Phillips station; two 80,000-kw units at Phillips station; and two 100,000-kw ur at the new Elrama station.

Mr. Atwell has been with Westingho Electric Corporation since 1917, when joined the company as a tester at the E Pittsburgh works. Two years later he came a design engineer and since that ti has been engaged in the development lightweight, high-speed motors and gene tors for electric transportation purposes, s as mine locomotives, street cars, trol coaches, diesel-electric buses and locomoti

Mr. Bergvall was assigned to the gene engineering department of Westinghouse East Pittsburgh where he worked until 19 In that year he became engineering mana for the company's Middle Atlantic Dist with headquarters in Philadelphia, and 1938 he returned to Pittsburgh as assist to the Vice-President. He assumed his p ent position in 1949.

Mr. Johnson co-ordinates engineer activities at Westinghouse on problems generation, transmission, distribution, system protection for electrical utilities large industrial plants. He joined company in 1941. Since then he has hand consulting engineering problems for electr utilities and manufacturing plants.

Mr. Lynn joined Westinghouse in 19 and a year later entered the power engin ing department as a designer of d-c mo and generators. In 1928 he was made tion engineer in charge of the design of motors and generators. In 1941 he awarded the Westinghouse Order of M

s outstanding engineering accomplish-
, and early this year was named engi-
ıg manager of the company's Atomic
r Division.

estic Appliances Conference Be Held May 15 in Columbus

e Committee on Domestic and Com-
ial Applications is sponsoring a technical
rence in Columbus, Ohio, on May 15,
y with the Columbus Section. The
theme of the conference will be Re-
h. The meeting will be held at Battelle
orial Institute in Columbus, and a trip
gh the Institute at 2:00 p.m. is sched-
as part of the all-day program. Dr.
ard W. Russell, Assistant Director of
lle Memorial Institute and Chief
icist, will speak at lunch on "Research
Consumer Acceptance."

esiding officers of the conference will be
. Reid, Chairman of the Subcommittee
omestic Appliances, and C. E. Warren,
airman of Columbus Section and Pro-
Chairman. C. F. Scott is Chairman of
Committee on Domestic and Commercial
ications, and Roger Merrill is Chairman
e Columbus Section, the joint sponsors
e conference.

otel reservations may be made at the
House or the Deshler-Wallach in Co-
bus. For further particulars and advance
tration, write to Jack P. Harris, Secre-
Committee on Domestic and Commer-
Applications, Cleveland Electric Illu-
ting Company, 75 Public Square,
eland 1, Ohio.

ne program for the conference is as
ws:

a. m.

ance Grounding and Its Safety Aspects. *H. B.*
ker, Associate Electrical Engineer, Underwriters'
ratories

Future of Research and Its Influence on Domestic
iances. *A. J. Nerad,* Director of Mechanical In-
ations, Research Laboratory, General Electric
pany

p. m.

New Developments in Structural, Thermal and
rical Insulation for Appliances. *W. Whitney*
, Owens-Corning Fiberglas Company

OMMITTEE ACTIVITIES

or's Note: This department has been created
he convenience of the various AIEE technical
nittees and will include brief news reports
mmittee activities. Items for this department,
h should be as short as possible, should be
arded to R. S. Gardner at AIEE Head-
ters, 33 West 39th Street, New York 18, N. Y.

eneral Applications Division

mittee on Production and Application
Light (*E. H. Salter, Chairman; R. C.*
am, Vice-Chairman; R. L. Oetting, Secre-
. Plans are now under development
a session as a part of the Fall General Meeting in Cleveland on the subject of "Selection of Circuit and Lamp Design to Conserve Critical Material." This session will be cosponsored by the Committees on Distribution Systems for Industrial Plants and Distribution Systems for Commercial Buildings. It is hoped to have papers describing some new lamp and circuit developments bearing on this subject along with papers on the selection of materials from presently available sources.

Looking forward to the next Winter General Meeting, ultraviolet radiation has been selected as the topic for a session at that time. The Subcommittee on Ultraviolet Radiations will present its report.

Industry Division

Committee on Electric Heating (*J. C. Handy, Chairman; P. H. Goodell, Vice-Chairman; Harold Bunte, Secretary*). The committee held a meeting in January which was well attended and great interest was shown in the discussion. A considerable number of papers were suggested for future meetings. In order to expedite the assembling of data and information on electrical heating problems, the Chairman appointed L. P. Hynes Chairman of a new subcommittee to be known as the "Technical Data Subcommittee."

The Subcommittee on Radiation Measurements Above 300 Mc, with R. M. Baker as Chairman, has almost completed its writing of "Recommended Practice for Measurement of Field Intensities above 300 Mc from Radio Frequency Industrial, Scientific, and Medical Equipments." When this is assembled, it will be submitted to the Standards Committee of AIEE.

The Subcommittee on Induction and Dielectric Heating, W. C. Rudd, Chairman, has written and the AIEE has published the report "Good Engineering Practice in Cases of Radio Interference." The compilation of definitions is completed and is now awaiting approval of the Institute of Radio Engineers. Equipment Standards are written and are being finally assembled. There is continued review and examination of Federal Communications Commission interference reports.

The Subcommittee on Radiant Heating, with I. J. Barber as Chairman, presented an informal report of a test of infrared for veneer drying which shows considerable promise. The new infrared lamp for electric ranges may develop into a form suitable for industrial applications, so its development is being followed with interest. Also the lack of agreement as to relative merits of infrared heat sources is being studied to see if some agreement can be reached on basic principles.

Committee on Industrial Power Systems (*J. S. Gault, Chairman; H. G. Barnett, Vice-Chairman; S. A. Warner, Secretary*). A meeting of the committee held at the Winter General Meeting was attended by 21 members of the committee. Also meetings of the Executive Subcommittee and the Subcommittee on Industrial Plant Grounding were held during the Winter Meeting.

This newly organized subcommittee on Grounding, under the chairmanship of D. L. Beeman, has been especially active during the past year, and promises to present some worth-while studies in this field in the near future, starting with one or two papers at the Summer General Meeting in Toronto.

The Subcommittee on Plant Distribution Systems, H. G. Barnett, Chairman, is working on the Red Book revision, also will have some papers to present at the Summer and Fall meetings. In co-operation with the Subcommittee on Interior Wiring for Commercial Buildings, B. F. Thomas, Jr., Chairman, a session is being planned for the Fall meeting in Cleveland, sponsored jointly with the Committee on Production and Application of Light, on the subject of "Selection of Circuit and Lamp Design to Conserve Critical Material."

Power Division

Committee on Carrier Current (*S. C. Bartlett, Chairman; C. W. Boadway, Vice-Chairman (East); R. H. Miller, Vice-Chairman (West); E. W. Kenefake, Secretary*). The several subcommittees of this group are continuing work, assembling material, tabulating data, and preparing progress reports, but at the same time we see a need to reconsider the objectives. When the matter of microwave applications was first added to the scope of this Committee there was some feeling that the members were not particularly interested or qualified to handle this subject. As time passed a somewhat different view was obtained both from the interest which has been shown in the subject and practical considerations in the art of power line carrier. There is some evidence leading to the belief that power line carrier may shortly approach its peak of usefulness since many systems are fully occupying the frequency spectrum and at the same time transmission circuits are being broken down by the introduction of many more substations, making them less suitable for carrier transmission. Carrier may reasonably be expected, as time passes, to be relegated to the duties of handling short-haul work. Microwave promises to be a practical means of replacing carrier for long-haul work and it will be the problem of communications engineers to consider these, together with all other communication means within a system, to keep pace with the expansion in operating requirements, at the same time accomplishing an orderly co-ordination or transition. This group therefore feels that the present arrangement of including microwave applications within its scope is entirely proper, and with minds receptive to ideas from all sources, it may be of some value to the Institute and to the industry in general through encouraging and participating in the development of all new techniques and combinations of systems.

Science and Electronics Division

Committee on Instruments and Measurements (*W. R. Clark, Chairman; J. E. Hobson, Vice-Chairman (West); J. H. Miller, Vice-Chairman (East); J. G. Reid, Jr., Secretary; W. S. Pritchett, Secretary (West)*). Three new subcommittees have been set up within the past three months. (1) Subcommittee to Formulate a Master Test Code for Speed Measurements. The Chairman of this Subcommittee will be Mr. E. R. Thomas, Consolidated Edison Company of New York, Inc. Its duties are to establish an AIEE Master Test Code for Measuring Speed as applied principally to Rotating Machinery. (2) Subcommittee on Recorders and Controllers. The Chairman of this Subcommittee is Mr. A. J. Hornfeck, of the Bailey Meter Company. Its function will be to sponsor papers and sessions on recording and controlling instruments, and assist in the preparation of terms used in these fields, and assist in the preparation of test codes wherever needed. (3) Subcommittee on Navigation Instruments. The Chairman of this Subcommittee will be Mr. E. J. Isbister, of the Sperry Gyroscope Company. Its function will be to sponsor papers and sessions on instruments used for all types of navigation, assist in the preparation of definitions of terms used in these fields, and assist in the preparation of test codes wherever needed. The AIEE Air Transportation Committee, the AIEE Marine Transportation Committee, and the AIEE Communication Division will all have representatives on this Subcommittee.

The Instruments and Measurements Committee has also been very active in the preparation of definitions for and specifications of various types of electronic instruments and in the formulation of an AIEE Master Test Code for Power Measurements. A report has been completed on the "Marking of Varmeters" and was presented at the Winter General Meeting. A report on the "Results of a Questionnaire Covering Current Practices in Electrical Tests on Dielectrics in the Field" has just been completed and will be presented at the forthcoming Summer General Meeting.

Committee on Therapeutics (*H. D. Moreland, Chairman; S. Reid Warren, Jr., Vice-Chairman; Scott W. Smith, Secretary*). The technical conference sponsored jointly by the Therapeutics Committee and the Electronics Subcommittee on X-Ray Tubes, Apparatus and Applications at the Winter Meeting represents a major step toward closer co-operation between the electromedical manufacturing industry and the Institute.

The combination of the Therapeutics Committee and the Subcommittee on Electrical Aids to Medicine into a single committee on "Electrical Techniques in Medicine and Biology" has been recommended by the two groups. It is believed that the union of these committees will strengthen the Institute's position not only in the electromedical branch of electrical manufacturing and application but also its co-operation with the medical profession.

AIEE PERSONALITIES . . . . .

D. C. Prince (A '16, F '26), Vice-President, General Electric Company, Schenectady, N. Y., has been named to the President's staff with special duties as assigned. Mr. Prince is a past President of the AIEE (1941–42), and Lamme Medalist (1945). He was born in Springfield, Ill., on February 5, 1891, and was graduated from the University of Illinois with a bachelor of science degree in electrical engineering in 1912, and with a master of science degree in electrical engineering in 1913. That same year he joined General Electric. A First Lieutenant in the United States Army for two years in World War I, Mr. Prince returned to General Electric and joined the research laboratory, where he conducted research on vacuum-tube applications. In 1929 he joined the Switchgear Department and shortly became chief engineer. He was appointed commercial engineer for the company in 1940, and the following year he was elected Vice-President and placed in charge of application engineering for the Apparatus Department. Mr. Prince was named head of the General Engineering Laboratory in 1945. He has been responsible for many important design developments not only in such fields as switchgear but also electric locomotives, ship control, electronic tubes, and many others. Mr. Prince has been an active member of the Institute serving as a Director (1938–44), and on the following AIEE Committees: Protective Devices; Lamme Medal; Edison Medal; Air Transportation; Technical Program; Hoover Medal Board of Award; Planning and Co-Ordination; and Executive. Mr. Prince is a member of The American Society of Mechanical Engineers and the Institute of Radio Engineers.

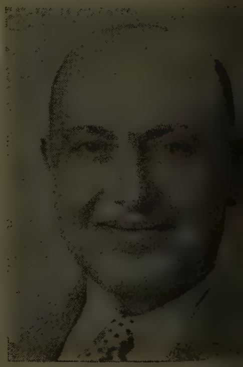
V. K. Zworykin (M '22, F '45), Vice-President, Technical Consultant, and Director of Electronic Research, RCA Laboratories
Division, Radio Corporation of Ameri
Princeton, N. J., has been awarded the 1
Medal of Honor by the Institute of Ra
Engineers for ". . . his outstanding contri
tions to the concept and development
electronic apparatus basic to modern t
vision, and his scientific achievements t
led to fundamental advances in the appl
tion of electronics to communications, to
dustry, and to national security." Born
Mourom, Russia, July 30, 1889, Doc
Zworykin was educated at the Petrog
Institute of Technology. Following a per
of graduate work in Petrograd, during wh
time he performed his first experiments w
television, he went to Paris in 1912 to en
at the College of France. At the end
World War I he came to the United Sta
joining the research Staff of the Westingho
Electric Corporation, East Pittsburgh,
While with Westinghouse, he carried out
vestigations in the field of photoelec
emission. Also, he resumed his research
television, developing the basic principles
the iconoscope. In 1929, Doctor Zwory
became Director of the electronic resea
laboratory of the Radio Corporation
America. He was appointed to his pres
position in 1947. His work led to the
velopment of such devices as second
emission multipliers and image tubes, as
as the electron microscope. He has recei
two degrees since coming to the Un
States: doctor of philosophy, in 1926, f
the University of Pittsburgh, and doctor
science, in 1938, from the Polytechnic In
tute of Brooklyn. Some of the awards he
received for scientific achievements are:
Lamme Medal for 1948 from the AIEE;
Morris Liebman Memorial Prize, 1934,
Overseas Award from the British Institut
of Electrical Engineers, 1939; the Rumf
Medal from the American Academy of
and Sciences, 1941; and the Howard
Potts Medal from the Franklin Instit
1947. Doctor Zworykin is a member of
Institute of Radio Engineers, the Ameri
Physical Society, the American Associat
for the Advancement of Science, and Sig
Xi. He is the coauthor of several books
photocells, television, electron optics,
photoelectricity.

L. J. Gorman (A '11, M '30, Member
Life), assistant engineer, Electrical En
neering Department, Consolidated Edi
Company, New York, N. Y., has retired a
40 years' service. He was born on Apri
1886, at Waddington, N. Y. After grad
tion from Clarkson College of Technolo
Mr. Gorman became associated with

D. C. Prince

V. K. Zworykin

L. J. Gorman


L. G. Pacent

ral Electric Company. In 1911, he
l the Testing Department of the New
Edison Company, to work on elec-
is surveys. Since 1921, he has had
e of all electrolysis surveys and mitiga-
n the company's pipe and cable systems.
n the electric utilities in the New York
became consolidated as The Consoli-
l Edison Company of New York, his
ties were augmented to meet the
ing demands of the entire electrical and
ystems. His studies in the field of elec-
ic corrosion of lead-covered cables and
pe-type feeders have been recognized as
er achievements in this area of opera-
Mr. Gorman is the author of several
ical papers on the specialized theory
practice of electrolytic corrosion. He
ecently become affiliated with the Robin
h Engineers Associated, Brooklyn, N. Y.,
e he will act as consultant in the field
ctrolytic corrosion. Mr. Gorman is one
e AIEE representatives on the Inter-
ty Corrosion Committee of the National
ciation of Corrosion Engineers. He has
d in this capacity since 1948.

. Pacent (M '18, F '30), President and
nical Director, Pacent Engineering
oration, New York, N. Y., has been
ded the Marconi Memorial Medal of
evement for his pioneer work in radio
communication. Mr. Pacent was born
ew York City on June 23, 1890, and
ded Pratt Institute where he studied
rical engineering with special study in
rical communication. In 1919 he
ded the Pacent Electric Company for
purpose of manufacturing radio equip-
t and electric devices. Seven years later
unded the Pacent Corporation and in
the Pacent Reproducer Corporation
begun. During the early part of his
r Mr. Pacent worked very closely with
ielmo Marconi. He has served the
tute on the Communications Committee
9–49), and is currently serving on the
E Board of Examiners. Mr. Pacent is a
w of the Institute of Radio Engineers,
Radio Club of America, and the Society
lotion Picture and Television Engineers,
a member of the Acoustical Society of
rica and the American Geographical
ety.

A. Edwards (M '40, F '47), associate
neer, General Engineering and Consult-
Laboratory, General Electric Company,
nectady, N. Y., has been appointed
neering manager of the laboratory.
or Edwards, in his new capacity, will be
onsible for all engineering activities of the
ratory and for engineering relations with
r divisions and departments of the com-
. He was graduated from Kansas State
ersity in 1928 and an honorary doctor
ience degree was conferred on him in
. Doctor Edwards joined General Elec-
in 1929 as a student engineer. Upon
pletion of his first test assignment, he
ed work as an engineer on television and
ed transmission problems. In 1945 he
appointed division engineer, and in 1949
ecame associate engineer in charge of the
ratory's technical divisions. Doctor
ards holds 82 patents for ideas developed
e field of industrial controls. He is cur-
y serving on the AIEE Research Committee. His engineering affiliations include: the Institute of Radio Engineers, Army Ordnance Association, and the American Association for the Advancement of Science.

C. Bradner Brown (A '37, M '47), chief, V-T Fuze Division, Naval Ordnance Laboratory, Washington, D. C., has been named to the position of technical assistant for the laboratory's new fuse program. Mr. Brown is a graduate of the University of Kansas, having received his bachelor of science degree in electrical engineering in 1931, and his master of science degree in 1933. He joined the Naval Ordnance Laboratory in 1941. His work there has been concerned with both magnetic- and acoustic-type mines and depth charges, as well as with various types of proximity fuses. Mr. Brown is currently serving the Institute on the Electronics and Basic Sciences Committees. He is also a member of Sigma Xi and the Society for Exploration Geophysicists.

F. K. McCune (A '33, F '49), assistant general manager, Nucleonics Department, General Electric Company, Richland, Wash., has been appointed manager of engineering of the company's large apparatus division in Schenectady, N. Y. Mr. McCune was graduated from the University of California in 1928 with a degree in electrical engineering, and that same year he joined the General Electric Company as a student engineer. He subsequently held positions in the International General Electric Company commercial department and in the General Electric West Lynn (Mass.) Works, where in 1945 he was named assistant works engineer. In 1949 he became assistant general manager of the Nucleonics Department. Mr. McCune served the Institute on the Transfers Committee (1946–48). He is also a member of Eta Kappa Nu, Sigma Xi, and Tau Beta Pi.

A. W. Edwards (A '43), design engineer, Protective Devices Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has won honorable mention in Eta Kappa Nu's outstanding young electrical engineer competition for 1950. He was born in Nashville, Tenn., on December 9, 1918, graduated from the University of Kentucky in 1937, and began work with the Westinghouse Electric Corporation after graduation in the graduate student training program. He was transferred to the Switchgear Engineering Department and his first engineering efforts were in the field of current-limiting power fuses. He has six inventions to his credit in the fuse field. During the ensuing years Mr. Edwards' field has broadened to include such devices as automatic circuit reclosers, load interrupter switches, fuse cutouts, automatic line sectionalizing devices, and other equipment associated with the distribution of electric power. This work has netted Mr. Edwards a total of 47 invention awards. He is also a member of the National Society of Professional Engineers.

W. L. Chadwick (M '38), manager, and **J. F. Davenport** (M '46), assistant Vice-President, Southern California Edison Company, Los Angeles, Calif., have been elected Vice-Presidents of the company. Mr. Chadwick was elected Vice-President in charge of engineering and construction. He joined the company in 1922, and became division engineer in 1924. From 1931 to 1937 Mr. Chadwick was senior engineer, and from 1937 he served as chief civil engineer until his appointment as manager of engineering. Mr. Davenport has been associated with the company since 1926. In 1929 he became hydro engineer, and in 1931 was appointed superintendent of hydroelectric generation for the company. He was named superintendent of generation in 1937, and assistant manager of operation in 1940. He was elected assistant Vice-President in 1946.

D. R. Yennie (A '47), graduate student in physics, Columbia University, New York, N.Y., is one of the scientists who has been named by the Bell Telephone Laboratories to receive one of the 1951–52 Frank B. Jewett postdoctoral fellowships. The awards, designed to stimulate and further the work of researchers in the physical sciences, grant $3,000 to the recipient and $1,500 to the institution at which he chooses to do his research. Mr. Yennie will receive his doctor's degree in physics this year from Columbia University, where he is studying on an Atomic Energy Commission fellowship. He received a master of engineering degree from Stevens Institute of Technology, Hoboken, N.J., in 1945, and was a physics instructor there in 1946–47. His research, dealing with the theory of elementary particles, will be conducted at the Institute for Advanced Study.

R. S. Kersh (A '42, M '45), manager, Central Station Sales Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named manager of the steam division, South Philadelphia, Pa. Mr. Kersh was graduated from Mississippi State College in 1929 with a bachelor of science degree in electrical engineering. He joined Westinghouse that same year and was assigned to the Industrial Sales Department. From 1931 to 1938 he was occupied with sales work in the Atlanta, Ga., and Birmingham, Ala., offices of the company, after which he returned to the East Pittsburgh plant as a member of the machinery electrification department. In 1942, Mr. Kersh was named manager of the company's Houston, Tex., office and remained until 1947, when he was appointed manager of industrial sales at East Pittsburgh. Two years later he was promoted to manager of central station sales, from which position he comes to his new duties.

Clarence Lynn (A '38, M '43, F '50), manager, D-C Generating Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed engineering manager of the atomic power division. Mr. Lynn was graduated from the University of Kansas in 1918 with a bachelor of science degree in electrical engineering. later entered the Power Engineering Department as a designer of d-c motors and generators. In 1928 he was made section engineer in charge of the design of d-c motors and generators. When the transportation and generator division was formed in 1938, he was made manager of the D-C Engineering

Department. In 1941, he was awarded the Westinghouse Order of Merit for his outstanding engineering accomplishments. Mr. Lynn has served the Institute on the following committees: Marine Transportation (1942–46, 1948–51); Rotating Machinery (1947–51).

E. M. Haacke (A '45), editor, *Electrical News and Engineering*, Toronto, Ontario, Canada, has been appointed Montreal branch manager, J. A. Wilson Lighting and Display Limited, Montreal, Quebec, Canada. Mr. Haacke is a graduate of Queen's University and his experience includes association with The Bell Telephone Company of Canada as a transmission engineer and as assistant editor and then editor of *Electrical News and Engineering*. During World War II, Mr. Haacke served as a radar officer in the Royal Canadian Air Force.

R. B. Bodine (A '37, M '45), sponsor engineer, central station engineering division, General Electric Company, Schenectady, N.Y., has been made manager of the large generator and converter sales division of the large motor and generator divisions. Mr. Bodine was graduated in 1936 from the University of Michigan with a bachelor of science degree in electrical engineering and mathematics. That same year he joined General Electric, and after three years in the company's advanced course in engineering, he was transferred to the central station engineering divisions. Mr. Bodine is also a member of Sigma Xi and Tau Beta Pi.

R. F. Field (M '40), engineer, General Radio Company, Cambridge, Mass., has retired after 21 years of service. Prior to his association with the General Radio Company, Mr. Field was a member of the faculty of Harvard University, Cambridge, Mass. He is well known for his work in impedance standardization, electrical measurements, particularly with bridge circuits, and the study of dielectric materials. Mr. Field, is a fellow of the Institute of Radio Engineers and the American Association for the Advancement of Science, and a member of the American Society for Testing Materials, the American Physical Society, Phi Beta Kappa, and Sigma Xi.

C. H. LeVee (M '42, F '50), sales manager, Wire and Cable Department, Eastern Division, United States Rubber Company, New York, N. Y., has accepted the position of Vice-President and chief engineer, Fagan Electric Company, Little Rock, Ark. He will also serve on the Board of Directors of Fagan Electric Company. Mr. LeVee is a graduate electrical engineer, having received his degree from Rensselaer Polytechnic Institute in 1924. Mr. LeVee is also a member of the American Military Engineers. In his new position, Mr. LeVee will have charge of all engineering and construction activities of the Fagan Electric Company.

J. L. Cox (A '46), chief engineer, Lamp Division, Duro-Test Corporation, North Bergen, N. J., has been appointed Vice-President in charge of manufacturing and engineering of its reactivated Electronics Division. Duro-Test Corporation curtailed its electronics subsidiary shortly after the end of World War II. The division is now being reorganized to contribute to the government's electronics defense program. Mr. Cox is regarded as an industry authority on gaseous discharge and electronic devices. He has several electronic inventions to his credit including the mercury bomb, the double cathode, and others.

R. E. Anderson (M '41), Vice-President, Delta-Star Electric Company, Chicago, Ill., has been named Senior Vice-President. In addition to his new duties Mr. Anderson will continue to direct the company's entire sales activities and commercial relations. His association with the Delta-Star Electric Company began in 1920 and he has advanced in the organization through positions as assistant sales manager, sales manager, and Vice-President. **C. S. Beattie** (M '40), Vice-President, Engineering Department, Delta-Star Electric Company, Chicago, Ill., has been appointed Executive Vice-President and general manager. In his new position Mr. Beattie will be in charge of all activites of the company. He joined the company in 1930 as sales engineer, and has successively been assistant sales manager, manager of engineering, and Vice-President in Charge of Production and Engineering.

E. S. Van Nostrand (M '46), operating superintendent, Southwestern Public Service Company, Amarillo, Tex., has been appointed manager of system planning for The West Penn Electric Company, New York, N. Y. Mr. Van Nostrand is a graduate of Lehigh University, class of 1925, with a degree of mechanical engineer. His previous experience includes association with the Philadelphia Electric Company and Pennsylvania Power and Light Company. From 1942 to 1945 he was with the War Production Board in the Power Supply Section of the Office of War Utilities. Mr. Van Nostrand is also a member of The American Society of Mechanical Engineers.

W. P. Shreve A '45), manager, transmission line material sales, General Electric Supply Corporation, Bridgeport, Conn., has been appointed assistant manager of the Pittsburgh District. Mr. Shreve joined the company at Oklahoma City in 1938 and became branch manager at Amarillo, Tex., two years later. In 1948 he was transferred to the general office at Bridgeport, and subsequently became assistant manager of power apparatus sales. He has been manager of transmission-line material sales since 1949.

S. S. Wolff (M '43, F '50), chief engineer, Century Electric Company, St. Louis, Mo., has resigned this position to become associated with the American Safety Table Company, Reading, Pa., in the capacity of chief engineer. Mr. Wolff graduated from the University of Illinois in 1922 with a bachelor of science degree. His previous experience includes association with the American Electric Motor Company, as chief engineer, and with the Burke Electric Company, Erie, Pa., in the same capacity. In 1940 Mr. Wolff joined the Century Electric Company as assistant chief engineer and three years later became chief engineer. He is currently serving the Institute on Rotating Machinery Committee.

P. F. Loftus (A '22, M '25), President, Pe F. Loftus Corporation, Pittsburgh, Pa., been awarded an honorary doctorate deg in engineering by the University of Otta Canada. He was graduated from University of Ottawa in 1911, and he a holds an honorary doctor of laws deg which was conferred in 1939. Mr. Lof has designed power plants for municipali both in this country and abroad. He also a member of the American Min Congress, National Society of Professio Engineers, and Pennsylvania Society Professional Engineers.

E. J. Rahill (A '32, M '48), division pl engineer, New York Telephone Compa Buffalo, N. Y., has been appointed Direc of Technical Advisers on the Civil Defe Staff for Buffalo and Erie County. T duties of this post include liaison betw the civil defense organization and Technical Societies Council in order obtain the assistance of outstanding men technical and scientific fields, whene their services are required for civil defe Mr. Rahill was previously engaged in c defense work during World War II.

R. W. Sorensen (A '07, F '19, Member Life), professor of electrical engineeri emeritus, California Institute of Technolo Pasadena, Calif., has been notified of election as an honorary member of Institute of Electrical Engineers of Jap Doctor Sorensen is a past President of AIEE (1940–41), and has been very act in Institute affairs. He is at present serv the Institute on the following committe Code of Principles of Professional Condu Members-for-Life Fund; Professional D sion Advisory; and Registration of Er neers. Doctor Sorensen is also a membe the Engineers Joint Technical Society Los Angeles, Calif., Sigma Xi, and T Beta Pi.

M. S. McIllroy (M '36), professor of el trical engineering, Cornell University, Ith N. Y., has been awarded the John M. Good Prize for 1950 by the American Water Wo Association. The certificate and cash aw are given to the member who has made most notable contribution to the science water works development during the ye Doctor McIllroy was cited for the devel ment of an electric apparatus to study p sure flows in pipeline networks. He graduated from Cornell University in 1 with a bachelor of science degree in electr engineering, and received a doctor of scie degree from the Massachusetts Institute Technology in 1947. Doctor McIllroy member of the American Society for En neering Education, Tau Beta Pi, Eta Ka Nu, and Sigma Xi. He is currently serv the Institute on the Computing Dev Committee.

C. V. Roseberry (A '47), supervisor, cen station division, Westinghouse Electric C poration, Los Angeles, Calif., has been pointed manager of the Central Station

ent. Mr. Roseberry received his
or of science degree in electrical engi-
g from Oklahoma Agricultural and
nical College in 1934. Following
tion he joined the Westinghouse Elec-
rporation and in 1936 was assigned to
n Francisco, Calif., office of the com-
s a central station salesman. In 1947
named assistant central station man-
or the Pacific Coast District, and two
later was appointed central station
isor for the Los Angeles branch
ry.

d Whitehurst (A '20, F '43), Vice-
ent, Electric Storage Battery Company,
elphia, Pa., has been named a Director
firm. He was born in Manchester,
nd, in 1893, and joined the company
08. In 1920 he was appointed as
ger of the company's Washington,
sales branch office and in 1940 he was
l assistant general sales manager. His
tment as Vice-President in charge of
followed in 1948. Mr. Whitehurst
the Institute on the Board of Exam-
1950–51). He is also a member of the
lin Institute, American Society of
Engineers, and the Society of Auto-
e Engineers.

Michell (A '20, F '49), general man-
Bolivian Power Company, Ltd., La Paz,
a, is retiring and **L. M. Howe** (A '37),
nt general manager, is succeeding Mr.
ll as general manager of the company.
Michell is a graduate in electrical engi-
g from the University of Manitoba.
ined the staff of Bolivian Power Com-
Ltd., in 1939. Mr. Howe was gradu-
rom the University of Manitoba with a
e in electrical engineering and he ob-
l his master's degree at McGill Uni-
y. He became associated with the
an Power Company in 1942 as super-
dent of the La Paz Division, and was
ting engineer and assistant general
ger before he was appointed to his new
on.

Moore (M '40), assistant chief engi-
Engineering Department, The Detroit
n Company, Detroit, Mich., has been
d the new President of Tau Beta Pi.
Moore received a bachelor of science
e in electrical engineering from the
ersity of Pennsylvania in 1920. He
associated with the General Electric
pany for five years and then in 1926 he
l The Detroit Edison Company. Mr.
e is also a member of Eta Kappa Nu.

V. Schweers (A '37, M '47), New
and regional manager, Allis-Chalmers
ufacturing Company, Boston, Mass., has
named director of sales of the company's
al machinery division. Mr. Schweers
l Allis-Chalmers in 1930 and has been
ected with the company's general ma-
ry division sales organization for more
20 years. **M. M. York** (A '43), man-
Boston district office, Allis-Chalmers
ufacturing Company, Boston, Mass.,
een named manager of the New Eng-
region. Mr. York became associated
Allis-Chalmers in 1939, and was a salesman in the Charlotte, N. C., district office for nine years before becoming manager at Boston.

G. M. Albrecht (M '17), patent attorney-in-charge, mechanical section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named special assistant to the general patent attorney. Mr. Albrecht was graduated from the University of Minnesota with an electrical engineering degree, and he received a law degree from George Washington University. Mr. Albrecht was employed as an examiner of patents in the United States patent office before joining Allis-Chalmers in 1918. He left the company in 1931 to practice patent law privately, but returned in 1946.

Joseph Chedaker (A '43), associate research engineer, Moore School of Engineering, University of Pennsylvania, Philadelphia, Pa., has joined the staff of the research division of the Burroughs Adding Machine Company, Philadelphia, Pa., as a research engineer. Mr. Chedaker was graduated from the University of Pennsylvania with the degree of bachelor of science in electrical engineering, and has been engaged in radio and electronic work since that time. He is also a member of the Institute of Radio Engineers and the Association for Computing Machinery.

F. P. Brown (A '44), electrical engineer, Midlothian, Ill., has joined the staff of the National Bureau of Standards as chief of the technical services section of the Ordnance Development Division. Mr. Brown received his bachelor of science degree in electrical engineering from the University of Michigan in 1932. His experience includes association with Commonwealth and Southern Corporation; Bechtel McCone Corporation; and The Pullman Standards Car Manufacturing Company.

A. M. Musgrove (A '30, F '45), Lieutenant-Colonel, United States Army, Dallas, Tex., has been promoted to the rank of Colonel in the United States Air Force. Colonel Musgrove is Director, Installations Engineering School, United States Air Force Institute of Technology. It is the purpose of the school to train Air Force officers to be management engineers of air bases. He served the Institute on the Transfers Committee (1947–48).

OBITUARY • • • • • •

Chester William Rice (A '13, M '26, F '39, Member for Life), retired, Boston, Mass., died on March 8, 1951. He was born on December 16, 1888, in Lynn, Mass. He received his bachelor of science degree in 1910 and his master's degree in electrical engineering in 1911 from Harvard University. Mr. Rice joined the General Electric Company that same year and was associated with the company until his retirement a few years ago. Mr. Rice was connected with the Consulting Engineering Department and had specialized in a number of fields, including sonic research. In 1932 he demonstrated a sonic locator which warned pilots of ships of fog-screened obstacles. Mr. Rice also invented a sonic altimeter which worked on the same principle, giving planes their distance above ground. He worked on submarine detectors, radar, and radio, holding a number of patents in these fields. Mr. Rice was an active member of the Institute, having served on the following committees: Education (1916–19); Electrophysics (1918–27); Communications (1922–28); Research (1928–33, Chairman 1932–33); Technical Program (1932–33); National Research Council, Division of Engineering (1932–35); Award of Institute Prizes (1932–33). Mr. Rice was also a fellow of the American Association for the Advancement of Science, the Acoustical Society of America, the American Physical Society, and the Institute of Radio Engineers; and a member of the Optical Society of America and the American Chemical Society.

George Albert Pierce (A '03, Member for Life), electrical engineer, retired, Philadelphia, Pa., died March 10, 1951. He was born on August 29, 1871, in Chester, Pa., and attended Drexel Institute. In 1895 Mr. Pierce became associated with the firm of William Cramp and Sons Ship and Engine Building Company, Philadelphia, Pa., as an electrical draftsman and became chief engineer in 1907. He developed and was granted patents for a system of submarine propulsion control from the conning station, for thermostats for use on shipboard, fire alarm systems, and several other devices. At the beginning of World War II, Mr. Pierce became principal electrical engineer associated with the Supervisor of Shipbuilding, United States Navy Inspector of Ordnance, New York, N. Y., and was responsible for the design and construction of electrical installations in many Naval vessels. He was a recipient of the Meritorious Civilian Service Award from the Navy Department in recognition of his services. Mr. Pierce was an active member of the Institute; he was one of the principal sponsors in the formation of the AIEE Committee on Marine Transportation and was a member of the committee from 1914–1942, and served as chairman, 1922–24, and 1926–27. He also served on the Meetings and Papers Committee (1922–24, 1926–27).

Frederic Streeter Brown (A '12, M '27, F '45, Member for Life), electrical engineer, Duquesne Light Company, Pittsburgh, Pa., died on March 4, 1951. He was born on February 9, 1886, in Lenox, Mass., and was graduated from Worcester Polytechnic Institute in 1908 with a degree of electrical engineer. After holding several positions in the power field, Mr. Brown joined the Duquesne Light Company in 1913 as a design engineer. For many years he was in charge of all substation and power station electrical design for the company. In 1945, he was named electrical engineer in charge of the Electrical Engineering Department and was responsible for all electrical engineering functions, and direction of the electrical station, transmission, distribution, customer services, and general engineering divisions. Mr. Brown served the Institute on the Electrical Machinery Committee (1944–47) and the Transportation Committee (1947–51). He was also a member of the Engineers' Society of Western Pennsylvania.

Robert Dale McCarter (A '99, M '09, Member for Life), consulting electrical engineer, New York, N. Y., died on March 9, 1951. Born in Emporia, Kans., on September 10, 1872, he was graduated in 1895 from Ohio State University with a degree of mechanical engineer in electrical engineering, and practised as a consulting engineer in the United States and Europe. He joined the General Electric Company in 1895 and in 1902 accepted the position of general manager and engineer to the Bath Electric Tramways Limited in England. Mr. McCarter's experience as a consulting engineer was extensive and included association with the London office of the General Electric Company, the European Westinghouse Electric Corporation, and the Westinghouse Russian Electric Society as President and managing director. From 1936 he was consulting engineer for large public utilities departments in Spain and Egypt. He was Vice-President of the European Gas and Electric Company of London and New York from 1930 to 1934. Mr. McCarter served on the War Production Board from 1942 to 1945. Later he was Executive Vice-President of American Chrome and Magnesium Industries, Inc., Seattle, Wash.

Jerome Douglas Burbank (A '26, M '34), electrical engineer, Worthington Pump and Machinery Corporation, died February 6, 1951. Mr. Burbank was born in Toronto, Ontario, Canada, on July 13, 1897, and was graduated from the University of Toronto in 1925 with a degree of bachelor of applied science. After graduation Mr. Burbank became associated with the Niagara, St. Catherine's, and Toronto Railway as a student engineer. In 1929 he assumed the position of acting engineer in charge of the carrier current telephone system of the Niagara Lockport and Buffalo Niagara and Eastern Power Systems. Mr. Burbank became employed by the Worthington Pump and Machinery Corporation in 1949. He was also a member of the Engineering Institute of Canada, the American Military Engineers, and the Institute of Radio Engineers.

Frederick Sawtelle Jones (A '14, M '41, Member for Life), staff engineer, Lubricating Oil Department, Socony Vacuum Oil Company, Inc., New York, N. Y., died on February 26, 1951. He was born on July 6, 1892, in Augusta, Me., and was graduated from the University of Maine in 1914 with a bachelor of science degree in electrical engineering. From 1914 until 1929 Mr. Jones was associated with the General Electric Company where he became a turbine specialist. In 1929 he became manager of the New England Division of the Technical Department of the Vacuum Oil Company. In 1932 when the company merged with the Socony Vacuum Oil Company Mr. Jones' title was changed to chief engineer. He was also a member of the Engineering Society of New England.

Jacobus Kappeyne (M '18), consulting engineer, Brooklyn, N. Y., died on February 22, 1951. He was born on August 3, 1882, in Amsterdam, The Netherlands, and was graduated from the Polytechnikum of Zurich, Switzerland, as a mechanical engineer. He came to the United States in 1905, became a naturalized citizen, and worked as a consulting engineer in New York City until his death.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners at its meeting of March 15, 1951, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Fellow

Chambers, C. C., acting dean; supervisor of research, Moore School of Electrical Engg., University of Pa., Philadelphia, Pa.
Cox, F. A., asst. to elec. engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Ferri, L. F., supervisor, relay application, Commonwealth Associates, Jackson, Mich.
Gilbert, J. J., submarine cable engr., Bell Telephone Labs., Inc., Murray Hill, N. J.
Greenfield, E. W., senior development engr., Kaiser Aluminum & Chemical Corp., Newark, Ohio
Hansell, C. W., research supervisor, RCA Laboratories Div., Rocky Point, N. Y.
Hutcheson, J. A., vice pres.; director of research, Westinghouse Research Laboratories, East Pittsburgh, Pa.
Leerburger, F. J., consulting engr., 250 E. 43rd St., New York, N. Y.
Maxwell, M. V., asst. engg. & service mgr., Westinghouse Electric Corp., Chicago, Ill.
Molina, E. C. D., mathematics lecturer, Newark College of Engineering, Newark, N. J.
Noest, J. G., div. engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Rankin, H. M., vice pres. & chief engr., Metropolitan Edison Co., Reading, Pa.
Shelleng, J. C., radio engr., Bell Telephone Laboratories, Inc., Deal, N. J.

13 to grade of Fellow

To Grade of Member

Abright, W. F., partner, Abright Electric Co., Dallas, Tex.
Adler, H. A., senior engr., Commonwealth Edison Co., Chicago, Ill.
Atkins, J. W., college instructor, Weber College, Ogden, Utah
Benckenstein, R. J., assignment engr., General Electric Co., Richland, Wash.
Benjamin, A. S., chief, sales methods div., Teletype Corp., Chicago, Ill.
Booth, C. E., elec. engr., Westcott & Mapes, Inc., New Haven, Conn.
Brauburger, R. A., laboratory engr., Chrysler Corp., Highland Park, Mich.
Brauch, H. N., design engr., Westinghouse Electric Corp., Sharon, Pa.
Burnett, W. C., div. transmission & protection engr., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Clevenger, C. M., elec. engr., Southern California Edison Co., Los Angeles, Calif.
Dexter, J. F., mgr., elec. section, Product Engineering Laboratory, Dow Corning Corp., Midland, Mich.
Faber, C. W., co-ordinating elec. engr., Brazilian Traction Group, Rio de Janeiro, Brazil
Fillmer, H. H., operation supt., Sho-Me Power Corp., Marshfield, Mo.
Foster, W. P., application & development engr., James G. Biddle Co., Philadelphia, Pa.
Hartsock, R. W., product section engr., Line Material Co., Zanesville, Ohio
Hedges, R. E., elec. engr., Douglas Aircraft Co., Santa Monica, Calif.
Horning, R. B., office mgr., General Electric Co., Charlotte, N. C.
Iyengar, K. R., chief engr., Kaycee Industries, Ltd., Bombay, India
Kelling, L. U. C., application engr., General Electric Co., Schenectady, N. Y.
Kerr, M. B., senior engr., Western Union Telegraph Co., New York, N. Y.
Kusko, A., asst. prof. of elec. engg., Massachusetts Institute of Technology, Cambridge, Mass.
Malkin, A., asst. chief plant engr., Canadian Car & Foundry Co., Ltd., Montreal, Quebec, Canada
Miller, M. V., electronics engr., Philadelphia Na Shipyard, Philadelphia, Pa.
Mumma, R. E., mgr., Electronics Research La National Cash Register Co., Dayton, Ohio
Ort, H. A., elec. engr., Packard Electric Co., St. Cath ines, Ontario, Canada
Parker, M. C., elec. engr., Bonneville Power Administ tion, Portland, Oreg.
Peabody, E. P., section elec. engr., General Elect Co., Richland, Wash.
Perrin, W. G., associate elec. engr., City of Glenda Calif.
Raines, W. A., sales engr., General Electric Co., N York, N. Y.
Rebholz, J. T., Jr., 45–55 Parsons Blvd., Flushing, N.
Roberson, D. A., elec. engr., Ebasco Services, In New York, N. Y.
Savage, P. L., mgr. engg. div., General Electric C Los Angeles, Calif.
Sawyer, S. P., elec. engr., Fitchburg Gas & Elect Light Co., Fitchburg, Mass.
Schultheiss, C. E., development engr., S & C Elect Co., Chicago, Ill.
Smith, W. L., development engr., The Electric Contr ler & Mfg. Co., Cleveland, Ohio
Treffeisen, R. E., requisition engr., General Elect Co., Schenectady, N. Y.
Vanaman, L. I., elec. engr., Knoxville Utilities Boa Knoxville, Tenn.
Vaughan, J. T., works mgr., tocco div., The Oh Crankshaft Co., Cleveland, Ohio
Watt, D. H., pres., Watt Plumbing, Airconditioning Electric, Tulsa, Okla.
White, M. F., chge. design & constr., Haydu Br Plainfield, N. J.
Yarbrough, C. T., mgr., electric service, Westingho Electric Corp., East Pittsburgh, Pa.

41 to grade of Member

Applications for Election

Applications for admission or re-election to Insti membership, in the grades of Fellow and Member, h been received from the following candidates, and member objecting to election should supply a sig statement to the Secretary before May 25, 1951, July 25, 1951, if the applicant resides outside of United States, Canada, or Mexico.

To Grade of Member

Brown, J. J. W., General Elec. Co., Schenectady, N
Coker, A. L., c/o William Jacks & Co. (Malaya) L Singapore, S. S.
Cook, R. A., 5130 Arcade Bldg., Seattle, Wash.
Cully, J. F., University of California, Los Alan N. Mex.
Dickerson, F. W., Graybar Elec. Co., New York, N.
Doede, H. O., Pioneer Service & Engg. Co., Chica Ill.
Friede, H. A. (re-election), Dist. of Columbia Go Washington, D. C.
Ganguli, S. C., Indian Post & Telegraph Worksho Calcutta, India
Gesell, W. B., Oklahoma Gas and Elec. Co., Oklahc City, Okla.
Gibson, A. C., Nashville Elec. Service, Nashville, Te
Gordon, M. F., Brown University, Providence, R. I.
Graham, H. C., Northern Elec. Co. Ltd., Toro Ontario, Canada
Hartley, H., The General Elec. Co. of India, L Bombay, India
Harvey, J. H. (re-election), U.S.B.R., Davis Dam,
Healy, E. S. (re-election), Ebasco Services, Inc., York, N. Y.
Hirsch, L. H., Century Elec. Co., St. Louis, Mo.
Horn, L. H., Underwriters Labs. Inc., Chicago, Ill
Houdek, J. F., Jr., Kellogg Switchboard & Supply Chicago, Ill.
Jones, E. D., 121 E. 3rd St., Charlotte, N. C.
Knecht, A. W., Seelye, Stevenson, Value & Kne New York, N. Y.
Lanford, C. C., Commission of Public Works, Gr S. C.
Lynch, P. G. (Miss), Automatic Elec. Co., Chicago,
Maddox, J. A. M., Byck Elec. Co., Savannah, Ga.
Marquardt, J. W., 332½ E. Adams St., Springfield,
Patterson, I. S., English Elec. Co. of Canada, Ltd., Catharines, Ontario, Canada
Rao, S. P., The Fertilisers & Chemicals, Travan Ltd., Alwaye, S. India
Revesz, G. L., Compagnie des Mines de Huaron, Jose por Shelby, Peru, S. A.
Richardson, R. B., Ebasco Services Inc., New Y N. Y.
Roach, F. J., Radio Corp. of America, Camden, N.
Short, W. E., Collins & Gould, Tulsa, Okla.
Slick, E. P., Capehart Farnsworth Corp., Ft. Wa Ind.
Smith, W. J., Commonwealth Edison Co., Chicago,
Strate, M. E., Geneva Steel Co., Geneva, Utah
Tench, A. O., Federal Power Comm., Chicago, Ill.
Tsang, N. F., University of Minnesota, Minneap Minn.
Walsh, R. N., International Tel. & Tel. Corp., York, N. Y.
West, R. H., University of California, Berkeley, Ca
Wojciechowski, B. M., Western Elec. Co., Inc., Kea N. J.

38 to grade of Member

F CURRENT INTEREST

ethods of Radio Astronomy Used to Study Total Eclipse

e National Bureau of Standards (NBS) cipated in an expedition to Attu d, Alaska, to observe the total eclipse e sun by the moon on September 11, . The expedition was organized prima- o apply the methods of radio astronomy e study of the eclipse at various radio encies.

addition to infrared, visible, and ultra- t radiation, the sun is continually giving nergy at radio frequencies. In recent , the techniques of radio astronomy been developed for receiving and yzing these longer wavelengths. This made it possible to obtain information t the positions of stellar bodies and er in interstellar space that could never been seen with an optical telescope.

e path of the total eclipse crossed ed States territory only on Attu, a small of land, the last and most westerly of Aleutian chain. While the climate of is most undesirable for making visual rvations with an optical telescope, it ed likely that significant results could btained there with radio apparatus.

The high-frequency energy from the sun was collected by a mirror ten feet in diameter having a focal length of three feet. An alti-azimuth mounting made it possible to sight the mirror on the sun. The mirror served to focus the incoming radiation on an antenna placed at its focal point and connected to a high-frequency receiver. Signals thus received were amplified and applied to an automatic recorder, providing charts of intensity versus time for various frequencies.

Measurements of solar radio intensity were made at wavelengths of 3, 10, and 65 centimeters. The receiving equipment for use at the 65-centimeter wavelength, which was supplied and operated by the NBS, was a superheterodyne receiver having a 30-megacycle intermediate frequency and two stages of radio-frequency amplification. The measurements were made from two to four times a minute beginning about two hours before the eclipse. The sky at an azimuth of about 90 degrees from the sun was used as zero reference. The sun was found to be quiescent and reasonably free from the transients which are often present during periods of solar activity.

Apparatus operated by the NBS on the Alaskan eclipse expedition. High-frequency radio waves from the sun were collected by the 10-foot radar mirror and focused on the antenna of a high-frequency receiver. Signals thus received were amplified and applied to an automatic recorder, providing charts of intensity versus time

Because of the radio waves sent out by the sun's ionized atmosphere, the apparent diameter of the sun at radio frequencies is always appreciably greater than at visual wavelengths. Consequently, all solar eclipses "viewed" with radio apparatus must appear to be annular rather than total. Preliminary results obtained from analysis of the data indicate that the apparent diameter of the sun exceeds that of the moon by 3, 7, and 11 per cent respectively at wavelengths of 3, 10, and 65 centimeters.

Besides the ionized atmosphere of the sun, a variety of other solar phenomena are effective in generating radiation at radio frequencies. For example, the magnetic field associated with sun spots causes additional radiation at centimeter wavelengths to originate in the neighborhood of the spots. Thus, as the edge of the moon first covered and later uncovered a spot group near the center of the solar disk, the observed intensity at radio frequencies dropped sharply and then rose again.

If the radio-frequency brilliance of the solar corona had been symmetrical, a minimum of observed intensity should have occurred at the time of optical totality. Actually, however, the minimums occurred a few minutes after totality at all three wavelengths. This was probably due to assymmetry of the corona caused by a group of spots near the east limb of the sun.

When the edge of the moon appeared just to touch the edge of the sun and at the instant when the edge of the moon finally left the edge of the sun, the apparent intensity rose about ten per cent above that of the unobscured sun. The explanation of this effect is not yet clear; it may be due to reflections of solar energy from the surface of the moon at grazing incidence. Diffraction around the edge of the moon could not have been the cause, as waves of kilometer rather than centimeter length would have been required. The possibility that this unexpected rise in intensity might have been caused by reflections from the landscape near the apparatus is under investigation.

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ure Meetings of Other Societies

ican Materials Handling Society. Materials ling Conference held concurrently with the Na- Materials Handling Exposition. April 30–May 51, International Amphitheatre, Chicago, Ill.

ican Society for Quality Control. Fifth National ention. May 23–24, 1951, Hotel Cleveland, land, Ohio.

ican Society for Testing Materials. Annual ing. June 18–22, 1951, Atlantic City, N. J.

ressed Air and Gas Institute. June 7–8, 1951, ew Country Club, Absecon, N. J.

erence on Industrial Research. Second Annual ng. June 11–15, 1951, Department of Industrial eering, Columbia University, New York, N. Y.

n Electric Institute. 19th Annual Convention. 5–7, 1951, Denver, Colo.

er New York Industrial Show. Sponsored by echnical Societies Council, May 7–11, 1951, egiment Armory, 34th Street and Park Avenue, York, N. Y.

inating Engineering Society. Great Lakes ng. May 24–25, 1951, Hotel Gibson, Cincinnati,

ution of Electrical Engineers. Conference on ical Instrument Design. May 28–31, 1951, The ution Building, London, England.

nal Conference on Airborne Electronics. Spon- jointly by the Professional Group on Airborne onics and the Dayton Section of the Institute of Engineers. May 23–25, 1951, Biltmore Hotel, n, Ohio.

y of Motion Picture and Television Engineers. Convention. April 30–May 4, 1951, Hotel , New York, N. Y.

y of the Plastics Industry, Inc., Annual National ng. May 24–25, 1951, Greenbrier Hotel, White r Springs, W. Va.

American Society of Mechanical Engineers. nnual Meeting. June 11–15, 1951, Royal York , Toronto, Ontario, Canada.

First Television Antennas Installed on Empire State Building Mast

Completion of the installation of the five television antenna arrays on the 222-foot mast atop the Empire State Building (*EE, Jan '51, p 2*) has been delayed because of the adverse weather conditions existing for 44 out of the 65 working days since January 1st above the 1,250-foot level at the base of the tower. As the work is being done from the top downward, the first transmitter to go on the air will be WNBT after the installation of the coaxial cable, automatic de-icing devices, and various cables, and after the completion of the operating tests. The other four stations are expected to begin transmissions

Electrician working on one of the television antenna units of the turnstile array on the Empire State Building tower topmost pole. The coaxial cable is inside the pole, which also contains power cables for de-icing the antennas

One of the turnstile antennas being hoisted to the WNBT section of the television tower on top of the Empire State Building. The 6 $^1/_8$-inch copper coaxial cable will be run through the circular openings in the platform gratings; power cables will be run inside the angle-members at the tower corners

at approximately monthly intervals as their installations are tested.

In discussing the million-dollar project, Dr. Frank G. Kear, consulting engineer of the project's primary committee, stated that the antennas of two more television transmitters could be accommodated on the tower and that these antennas could be installed at a later date without interrupting the transmission of the five other stations.

While work on the tower and antennas has been progressing, three television transmitters have been installed on the 89th and higher floors of the building and work on two more has been started. When the five station transmitting simultaneously, no one sta will have any advantage over any of others because of its antenna's relative tion on the tower; each station will have same opportunity to cover the same area the same signal strength.

New Push-Button Communication Center Replaces Manually Controlled System

The electric impulse which turned on the new push-button communication center at American Steel and Wire Company, Cleveland, Ohio, was obtained by the fusing of a wire suspended above an iron trough at one of the company's Cleveland blast furnaces. The private telegraph switching center will speed the flow of messages between 149 United States Steel plants and offices in 86 cities. The new center replaces a manually controlled center which has been in use for many years.

The electric impulse which turned on the equipment was obtained by placing a loop of fusible wire 12 inches above an iron trough. After the furnace was cast, hot iron flowed through the trough at a temperature of 2,650 degrees and melted the wire loop. This broke an electric connection, activating a relay, which in turn pushed a button energizing the telegraphic apparatus.

The push-button center gets its name from the fact that the time and effort of switching an incoming telegram to its destination is reduced, by means of complex equipment, to the simple expedient of pressing a button. The new apparatus replaces the old cord-and-plug type of operation.

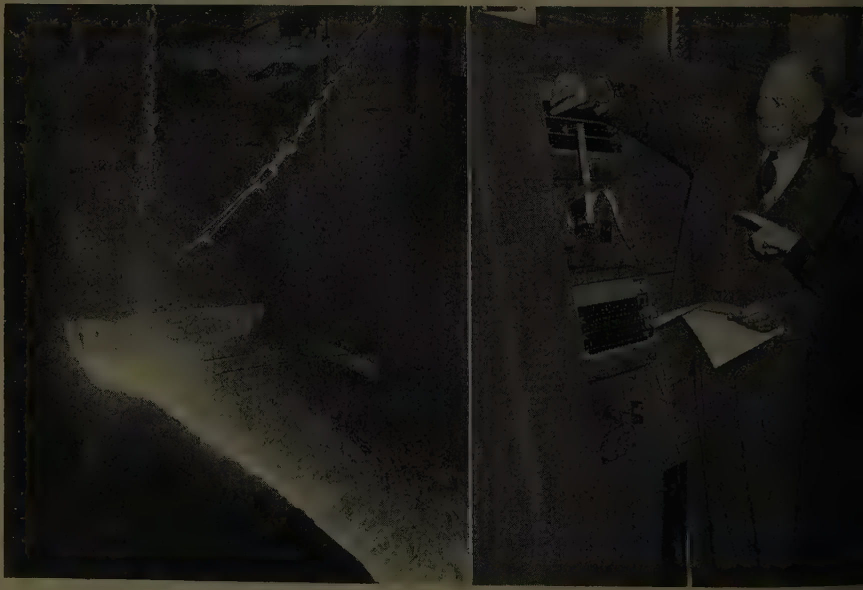
Through the new system, each message is typed only once on the typewriter-like keyboard of a teleprinter at the origina point, and flashes to the center. There operator observes the destination on a forated tape, touches the proper button, an electric "brain" flashes the message a circuit leading to its destination.

One feature in the new service of the center is a master push-botton panel which a telegram can be transmitted si taneously to numerous offices and plan

A printer perforator receives the sig from an incoming circuit and prepares tape with printed characters on the u edge and perforated combinations re senting letters directly below. Each pri perforator has an associated transm which can be connected with any outg circuit in the center by means of the p button.

A vigilant monitor system protects center against any failures. Associated each telegraph circuit is an autor "remembering" machine—a message-n bering device which transmits a grou letters identifying the center at which switch is made and the station to which message is being routed. This machine serts an identifying channel number pric the transmission of each message.

An additional safeguard is a group



The electric impulse which turned on the new push-button communication cente American Steel and Wire Company, Cleveland, Ohio, was obtained by the fusing wire suspended above the iron trough at one of the company's blast furnaces. T broke a connection, activated a relay, which in turn caused an "automatic fing which is being indicated by Mr. H. B. Jordan, President, to energize the telegrap apparatus

y printers" which automatically record
op line of every message transmitted
gh the center. This maintains a com-
and continuous record, available for
ediate reference at any time.
ore than 270 miles of wiring and over
00 hand-soldered connections were in-
d in the installation of the new center.

ple Gauge Performs
iracles of Measurement

simple gauging device the size and thick-
of a postage stamp can measure minute
extremely heavy loads, dimensional
ges of 1×10^{-6} inch, or temperature
ges ranging from near absolute zero to
degrees above. Mr. Francis G. Tat-
Manager of Testing Research at Bald-
Locomotive Works, Philadelphia, Pa.,
ribed the instrument at the annual
ing of the American Society of Tool
neers.
e simple device consists of a wire one-
the thickness of a human hair which is
d back and forth, then coated with
nt. If the gauge is distorted so that the
is stretched or contracted, its resistance
assage of an electric current is varied.
surement of the variation tells the exact
unt of stretch. The instrument will
rately measure a dimensional change of
10^{-6} inch in one inch of length.
e application of the gauge is in testing
ary jet engine blades while they are in
ation. The gauge is cemented to the
e, a current passed through it, and the
e is run. Any bending of the blade
hes the wire and changes its conductiv-
which then is registered on a meter.
the engineers can tell exactly what is
ening to a spinning blade while the
e is in operation.
nversely, to weigh the load on a bridge,
auge is cemented to one of the supports.
ange in load causes the support to give a
amount. This is immediately regis-
by the gauge. Simple calculation then
mines the exact load that caused the
ort to give.

ford Studies Industrial
emand for Fission Products

w constructive, industrial uses for by-
ucts of the atomic energy program,
gh the medium of large-scale employ-
of fission products, are being investi-
on a nation-wide basis by Stanford
arch Institute for the United States
ic Energy Commission.
e immediate objectives of the study are
cquaint industrial concerns with the
acteristics of fission products and to ob-
the co-operation of industry in develop-
stimates of their possible utilization.
e atomic by-products known as "fission
ucts" are a highly radioactive mixture
ements produced by the fission or split-
of uranium during the plutonium pro-
on process in nuclear reactors. These
active atoms have no usefulness for in-
ial or explosive power but only for the
etic radiations which they emit. Large
tities of fission products left over from
nium processing now are stored in a mixture with contaminants in underground tanks at the Hanford, Wash., works.

As a result of this study, industry may be offered an opportunity to tap large-scale, low-cost sources of radioactivity. The cost should be substantially lower per unit of radioactivity than presently available sources. For example, the cost per curie of fission products in large quantities is estimated to be in the range of 0.01 to 0.001 of the price of most radioactive materials which are presently available.

Attending the unveiling of the 14-foot model of the Empire State Building television antenna mast at the Institute of Radio Engineers' Convention were: left to right, George Sterling, FCC Commissioner; Comdr. M. W. Lowei, Director, Du Mont TV network; Frieda Hennock, FCC Commissioner; Lt. Gen. Hugh Drum, Pres. Empire State Building, Inc.; Brig. Gen. David Sarnoff, Chairman of the Board, RCA; P. B. Stephens, business manager, N. Y. Daily News; E. M. Webster, FCC Commissioner; Kay Burke, "Miss Empire State"; E. J. Noble, Chairman of the Board, American Broadcasting Co.

New Radioisotope Service
Offered at Brookhaven Laboratory

Special radioisotope distribution and irradiation services utilizing the new nuclear reactor at the Brookhaven National Laboratory at Long Island, N. Y., have been authorized recently by the Atomic Energy Commission (AEC).

The AEC laboratory at Brookhaven will specialize in the production of highly radioactive isotopes and short half-life isotopes that cannot be effectively shipped to the Brookhaven region from Oak Ridge, Tenn., or other distant locations.

Inquiries concerning the new Brookhaven services may be addressed to the Isotopes and Special Materials Group, Brookhaven National Laboratory, Upton, N. Y. Requests for radioisotopes or irradiation services should be made to the AEC Isotopes Division, Oak Ridge, Tenn.

Institute of Radio Engineers
Holds 40th National Convention

The 40th annual convention of the Institute of Radio Engineers (IRE) was held on March 19–22, 1951, in New York, N. Y., with a registration of 18,000 members representing 31 countries. The annual Radio Engineering Show, with 279 exhibits of the latest electronic apparatus, was held at Grand Central Palace.

More than a third of the papers delivered at the meeting dealt with color television signal generation, transmission, reception, and the engineering aspect of color reproduction by television picture tubes.

Military items such as atomic piles, radar, guided-missile controls, and gun-laying computers were discussed. Communications and warning apparatus using electron tubes and needed for civilian defense received attention.

New Radio Attachment
Eliminates Commercials

A new device which completely and automatically eliminates commercials from broadcast programs without losing a note of the music was described and demonstrated at the annual convention of the Institute of Radio Engineers (IRE). It contains in its present form only four ordinary radio tubes, and it can be attached to any existing set.

Invented and perfected by Dr. R. Clark

Jones of the Polaroid Corporation of Cambridge, Mass., this bit of modern electronic magic "listens" for a program's pauses and measures their abruptness, remembers how many have passed during the preceding seconds of the program, and makes its decisions accordingly. It can even distinguish between singing commercials and other music. The automatic commercial-silencer was evolved by Doctor Jones from the ever-broadening field of the electronic calculator.

It is completely automatic in operation when attached to a radio or television set. It is quite simple and reliable, but required months of research to produce. It makes use of five inherent functions of the ordinary electronic calculator—it extracts logarithms, it integrates values, differentiates, subtracts, and can "remember." Doctor Jones developed the device in his spare time, as a hobby.

New Device Used to Record Technical Data Simultaneously

A technique for recording simultaneously both the radioactivity and rock strata resistance in underground drilling operations and for other industrial and scientific applications was announced recently by the Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.

The new system consists of an electronic recording instrument for obtaining, in a single operation, data of great value in searching or drilling for oils, minerals, and water. The same device may also be used for spectrometer analyses and in meteorology for recording wind velocity and direction and to measure tide levels and currents simultaneously.

Previously, separate measurements have had to be taken for two sets of data by making two "passes," one up and one down. Now a 2-pen electronic recorder enables drillers to get the same results at greater speed and with a saving in man power. The simultaneous recordings of the new device require only one recording "pass," permitting speedy withdrawal of an entire electrode from a well.

The speeds of descent and ascent of drilling apparatus had to be equal under the old systems, causing frequent errors when a correlation of separate records was attempted. By the new method, the correlation is automatic.

Other applications for dual or simultaneous recording were said to include the measuring of effectiveness of mechanical coating process on a transparent film or other base. In this application one record will show the density of the coating of a product as it emerges from a process, the other shows density before coating, the arithmetical difference providing a quantitative measurement of coating density.

NAM Recommends that Civilians Advise on Mobilization

The appointment of an "essentially civilian" commission to advise President Truman and the Director of Mobilization on the continued supply and efficient use of technological man power, of which a critical shortage exists, is being recommended by the National Association of Manufacturers (NAM).

The ability of industry to meet defense or war production demands depends on an increasing flow of scientific and engineering graduates, it is emphasized in a current report by the association's Research Committee. It is pointed out in the report that there is already a shortage of engineers, and an impending shortage of 40,000 engineering graduates by 1954, even if none were drafted. The shortage of scientists in numerous fields is also critical. A particularly serious aspect of the technological man power shortage is that 25 per cent of the technically trained men in industry are reservists in the armed forces. Withdrawal of these men from industry is now entirely in the hands of the Department of Defense.

The committee recommends that ". . . an essentially civilian commission, comprised of men of established eminence and integrity and familiar with the role of technology in national affairs, should be appointed by the President to advise him and the Director of Mobilization from time to time on the supply and efficient utilization of technological man power, including those in military reserve status."

Function of National Inventors Council in the Defense Program

The National Inventors Council functions in an advisory capacity to the Department of Defense and other departments, agencies, and offices of the government in evaluating, guiding, and analyzing inventions for the national defense and security. The Council membership comprises outstanding American inventors, scientists, and industrial research men having specialized experience in the development and utilization of inventions, together with the Commissioner of Patents and a representative of each of the three branches of the Armed Services.

The Council was originally created in the fall of 1940 by the Secretary of Commerce with the concurrence of the President. During the war years the Council screened over 200,000 inventions for the Armed Services. Many of them played an important part in the war—the magnetic mine detector, for example. Since then the Council has continued to function in the Commerce Department in accordance with the recommendations of the Department of Defense.

Besides acting in an advisory capacity on questions of national security and welfare, the Council functions to encourage the public to submit inventions or inventive ideas of value in the defense and welfare of the nation and to acquaint the public with the problems confronting the Armed Services, and refers all potentially valuable ideas to the Department of Defense or other appropriate agencies.

No special forms are required for submitting proposals to the Council and the services of an attorney are not essential. Consideration of inventions is facilitated if each proposal is submitted as a separate document, preferably typewritten, containing complete information on the principles underlying the operation of the apparatus or invention together with a discussion of any tests which have been conducted and the p ticular points of novelty or superiority of inventions as compared with existing devi or practices.

The following partial list of technical pr lems on which information is needed has b compiled by the National Inventors Cour with the co-operation of the Armed Servi All of these technical problems affect natio defense: To Provide for the Rapid Splic of Assault and Field Type Wires; Snow hicle; Machinery for Fabrication Method of Welding Titanium; Adhesive Explosives; Adhesive Tape, Industri Automatic Coupling Joint; Lightwei Unicellular Foam Filler for Field Manu ture; Radical Methods of Ship Dischar Snow and Ice Mole; A Personal Heat System; Practical Method of Destroy Tell-Tale Tracks of Men on Foot or Vehi Across Snow Fields; Supply System for on Glaciers; Stabilization of Flat Surfa Inexpensive Method for Rapidly Convert Snow and Ice into Drinking Water in Qu tity; Heating Clothing for Personnel Low-Activity-Level Occupations; Mate for Arctic Gloves Resistant to Deteriorat by Oil and Gasoline; Device for Protect of Head and Respiratory Tract Agai Cold; Engine and Personnel Heat Means of Individual Protection from Gam Radiation; Method for Prolonging the P ervation of Whole Blood; Accurate In ment and Technique for Barometric Le ing; Technique, Method, and Equipment the Detection of Buried Explosives; Ra Automatic Methods of Determining the of Smoke Particles and the Obscuring Po of the Smoke.

Basically, these problems are distribute find the best existing solutions and promis ideas which may lead to better soluti Anyone who has such information is ur to communicate with the National Inven Council, Department of Commerce, Wa ington 25, D. C.

All ideas and suggestions submitted to Council are carefully screened. Whe proposal appears to be constructive, Council refers it to the appropriate techn branches of the Armed Services for stu The judgment of the Armed Services c cerning the matter is communicated to inventor as soon as possible.

It should be emphasized that these pr lems are not released in an attempt to firms and organizations interested in obt ing development contracts from the Ar Services. Those concerns interested in velopment contracts should discuss the n ter directly with the technical branch of Armed Services in their field of specializat What the National Inventors Council s to do is bring these problems to the atten of individual inventors, scientists, and e neers. Through this technique, their structive thinking is applied to the techn needs of our Armed Forces.

Water Resources Policy Commission Report Completed

The President's Water Resources Po Commission, which was appointed in Jan 1950 to study and make recommendation policies in the field of water resources, gether with existing legislation, has just leased to the public the last of its 3-vol and, having completed its assignment, ne out of business.

Commission's main report, Volume 1, d "A Water Policy for the American ," offers a co-ordinated national pro- or the development of water resources, er with specific recommendations on Volume 2, "Ten Rivers in America's ," is a study of ten river basins in differ- rts of the country and includes a de- discussion of the problems of each basin mass of pertinent material never here- published. Each of these basin stud- is been published separately. The volume, "Water Resources Law," sum- s Federal law concerned with the 's water resources.

4-page pamphlet containing the Com- n's summary of recommendations, re- d from Volume 1, gives a concise idea scope and content of the report. of each volume, the Summary of nmendations, and the ten river-basin may be purchased from the Super- ent of Documents, Washington 25, at the following prices:

1: "A Water Policy for the American e"	$3.25
2: "Ten Rivers in America's Future"	6.00
3: "Water Resources Law"	2.25
ry of Recommendations	0.15

separate sections of Volume 2 may be r prices varying from 50 cents to $1.00. eries includes the Columbia, Missouri, rande, Colorado, Connecticut, Ala- Coosa, Potomac, Ohio, the Tennessee , and the Central Valley of California.

oit Edison Company Orders a ird New Steam Turbogenerator

Detroit Edison Company has ordered rd 125,000-kw (166,000-horsepower) turbogenerator for its new St. Clair plant. Two similar generators for the now under construction on the St. River front three miles north of Marine Mich., already are being built.

acity of the St. Clair generating sta- is now planned, will be 375,000 kw— 0 horsepower. When the new equip- is in full operation, late in 1953, maxi- capacity of the Edison system's five will total about 3,000,000 horsepower, than twice that of 10 years ago.

avation for the new St. Clair plant ng has already begun, and pile-driving foundations is to start soon. Material e foundations of the additional turbo- ator was included in the original con- ion plans and a supply of structural steel third unit is on order.

osium on Nuclear Engineering ll Be Held at Oak Ridge

1951 Summer Symposium in the series red annually by the Oak Ridge Na- Laboratory and the Oak Ridge Insti- f Nuclear Studies will be held from t 27 to September 6, 1951, at Oak , Tenn.

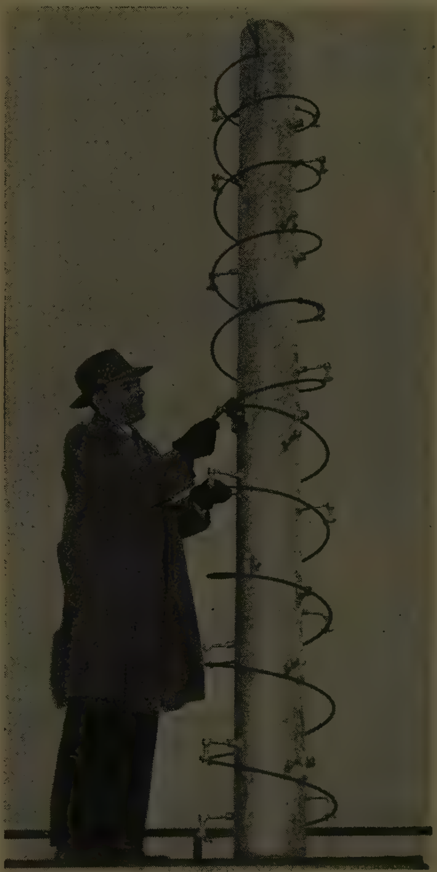
ions in the 1951 symposium will be d to nuclear engineering, at the request American Society for Engineering Education. Representatives of interested industrial organizations are invited to join the Atomic Energy Commission personnel and representatives of educational institutions in discussions of basic nuclear engineering, general nuclear power philosophy, applications of the engineering sciences to nuclear technology, and the problems of nuclear engineering education.

Inquiries concerning participation in the symposium should be addressed to Dr. Russell S. Poor, Oak Ridge Institute of Nuclear Studies, Post Office Box 117, Oak Ridge, Tenn.

New Ultrahigh-Frequency Transmitter Built by GE

Announcement has been made of the development of a new 5-kw ultrahigh-frequency television transmitter by the General Electric Company, Electronics Park, Syracuse, N. Y. The transmitter system will have an effective radiated power of 100 kw and will operate in the 500-megacycle region. This is made possible by the development of a new type of ultrahigh-frequency velocity-modulated 5-kw tube, and a new type of antenna which increases the effective radiated power by 20 times.

The General Electric Company has requested permission from the Federal Communications Commission to operate the ultrahigh-frequency transmitter on an experimental basis, and when granted, will make field reception tests.



One section of the new type of television transmitting antenna developed by the General Electric Company which will be used for high power ultrahigh-frequency telecasting. The new antenna, which will be made up of four sections like the one shown, will increase the effective radiated power of the ultrahigh-frequency transmitter by 20 times

Scientists Urgently Needed by the National Bureau of Standards

The National Bureau of Standards, Department of Commerce, urgently needs competent scientists in the fields of electronic science, engineering, and physics. Specialists in these fields in the Bureau will be engaged mainly in work which represents research and development needed by the Department of Defense. The work offers opportunities for professional growth and advancement and may often form the basis for a doctor's thesis.

The most urgent need for engineers and physicists is at starting salaries ranging from $4,600 to $8,800 a year.

Applications for scientific positions are being accepted by the United States Civil Service Commission, Washington 25, D. C., under Announcement *Number 226* for Physicist, Chemist, Metallurgist and Mathematician, and its amendment for Electronic Scientist. Details about the requirements of experience and/or education, as well as other requirements, are given in the announcement and amendment.

Applications may be obtained from most first- and second-class post offices, from Civil Service regional offices, or from the Commission's Washington office.

Radar Unit with 100-Mile Range Installed in Chicago, Ill.

A complete radar unit with a range of 100 miles is being installed at Illinois Institute of Technology, Chicago, Ill. The unit will be used in advanced electrical engineering courses to demonstrate principles and application of ultrahigh frequencies.

While the unit, one of the largest naval airborne types developed in World War II, could be used in civil defense, it was designed for land and water search.

The equipment, obtained through the War Assets Administration, is being installed on the roof of the Main building, 33rd and Federal streets, under the direction of Mr. Charles Benz, electrical engineering department technician, and Mr. Lewis Ebinger, department instructor.

Westinghouse Educational Foundation to Grant Fellowships

Between 20 and 40 fellowships, each valued at $250, will be awarded to secondary school science teachers who will particpate in a special six weeks' summer program at Carnegie Institute of Technology, Pittsburgh, Pa. The fellowships have been made available by the Westinghouse Educational Foundation, which is maintained by the Westinghouse Electric Corporation.

The program of study will stress the importance of fundamental concepts in chemistry, physics, and mathematics, and will provide a survey of recent developments in the pure and applied sciences. The academic program will consist of lectures on such topics as radioactivity, nuclear research, synthetic rubber, petroleum, and applied mathematics. It will be supplemented by visits to Carnegie Institute of Technology's research and teaching laboratories and to some of the industrial establishments of the Pittsburgh area.

The program will provide six hours of credit for teachers who are seeking credits for advanced degrees. Full-time staff members of the college of Engineering and Science will have charge of the course.

The program will begin Monday, July 2, and extend through Friday, August 10, 1951. Saturday sessions will be held. A tuition fee of $50.00 will be charged for the 6-week course and the balance of the $250.00 fellowships can be applied to commuting or living expenses. Living accommodations in Carnegie dormitories will be available at reasonable rates, and dining facilities are available on the campus. The school's recreational facilities will be available without charge to fellowship winners.

Application forms and further information about the summer program can be obtained from the Director of Admissions, Carnegie Institute of Technology, Pittsburgh 13, Pa.

Cornell to Offer Special Summer Program of Study

A special program of advanced study for teachers of engineering will be offered by the College of Engineering at Cornell University, Ithaca, N. Y., during the university's summer session July 2–August 11, 1951.

The six courses are intended for instructors in mechanics, structures, and similar subjects. They will be taught by members of the Cornell engineering staff and will provide opportunity for individual study of particular interest to the student.

Each course carries three hours' credit. Two may be taken during the session. Inquiries should be addressed to Professor Conway, West Sibley Hall, Cornell University, Ithaca, N. Y.

Brooklyn Polytechnic Institute Resumes Its Annual Open House

A decade of advancement in engineering and science was revealed to the public when the Polytechnic Institute of Brooklyn, N. Y., founded in 1854, opened its laboratories and shops to visitors for the first time in ten years. The occasion was the resumption of its Annual Open House.

The great strides made in the advancement of science and engineering since the last Open House was held a decade ago were reflected in the vast variety of exhibits and demonstrations. The deans and heads of departments were available to advise those who are interested in preparing for engineering and scientific careers.

Among the many events scheduled was a lecture demonstration on "Seeing Atoms with X rays," given by the Department of Physics. Visitors to the Internal Combustion Laboratory witnessed a Ford V-8 engine operated by manufactured household gas as well as an engine "knock performance" test displayed by the Department of Mechanical Engineering. The latest concepts in experimental communications and electronics circuits were demonstrated by the Department of Electrical Engineering and advances in aeronautical engineering were exhibited in the aerodynamics laboratory wind tunnel; the tailspin, wing flutter, and other aeronautical phenomena were shown.

National Electronics Conference. Authors of papers to be presented at the 1951 National Electronics Conference should submit titles and 200-word abstracts to Dr. J. D. Ryder, Chairman of the program committee, not later than May 15, 1951. Titles and abstracts should be sent to Doctor Ryder at the Electrical Engineering Department, University of Illinois, Urbana, Ill.

Electrically Operated Pump Increases Phoenix Water Supply

A daily increase of 20,000,000 gallons of water has been made possible through the use of an electrically driven booster pump at Phoenix, Ariz. A booster station uses an 800-horsepower motor made by the General Electric Company to drive the pump. A 5-horsepower motor operates a valve which connects the pump to a 48-inch main.

Cost of the city's installation is about $70,000—a fraction of the estimated $400,000 cost of a new pipe line with the same capacity.

Because of the large increase in the number of water customers during the past year, the booster station was needed to step up city's daily capacity of water lines fr the Phoenix supply source on Verde Ri The total number of Phoenix water custom has jumped more than 11,000 in the past y

The pump has a peak capacity of 50, gallons per minute, or 72,000,000 gallons day. The pipe line's capacity could be creased only by 20,000,000 gallons per da

Engineers Joint Council Meeting Held on March 16

The Engineers Joint Council (EJC) its regular meeting in the Engineering cieties Building, New York, N. Y., on Ma 16, 1951. James E. Todd, Chairman, sided.

The Executive Committee reported T. E. Purcell had been asked to head a c mittee to follow legislation relating to pollution and to appoint other engineer serve with him. It had also asked E. S. to make a study of possible EJC interes patent protection and to report to the c mittee.

For the Engineering Man Power C mission, E. G. Bailey, temporary Chairm presented a progress report. He announ the imminent selection of a chairman an executive secretary. (At a meeting of Commission on March 27, 1951, C. H. Br took over the chairmanship and T. Marshall, Jr., the executive secretarysh A communication on the need for enginee under preparation and will be sent to al 25,000 high-school principals, and to equal number of teachers of science mathematics.

LETTERS TO THE EDITO

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication in no wise constitutes endorsement or recogni by the AIEE. All letters submitted for publica should be typewritten, double-spaced, not car copies. Any illustrations should be submitte duplicate, one copy an inked drawing wit lettering, the other lettered. Captions should supplied for all illustrations.

Correction on Whitehead Digest

To the Editor:

I am sorry to note a serious error in the printing of the digest of my recent paper, "Stresses in Impregnated Paper Insulation," which appeared on page 297 of the April 1951 issue of *Electrical Engineering*. The illustra and caption used for Figure 2 are incorr

J. B. WHITEH

(The Johns Hopkins University, Baltimore,

(*Editor's Note:* The correct Figure 2 wit caption are reproduced on this page.)

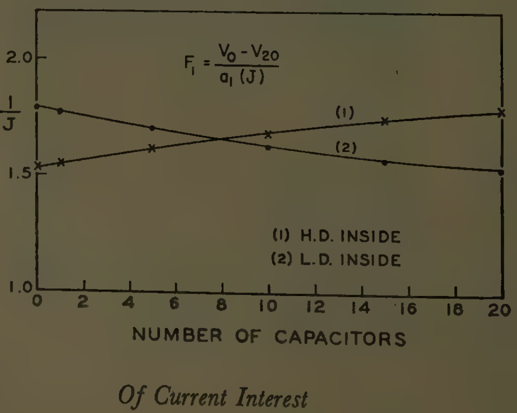
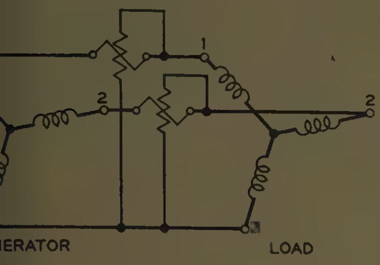


Figure 2. Graded cable. V ation of maximum oil stress relative radial depths of a d and of a less dense pape

rmining Phase Sequence

Editor:

s frequently desired to establish the sequence and proper terminal mark- 3-phase lines, motors, and generators. checking a number of textbooks and ooks dealing with this problem, I ar- the conclusion that the following fact generally known. The ordinary 2-eter method of measuring power yields



e 1. Schematic diagram for determining phase sequence

atically the desired answer. The orerequisite is a reasonably balanced ot at unity power factor. Every 3- induction motor fulfills this require- regardless of the load condition under it may be operating.

hown in Figure 1, denote with "3" the hich is common to the potential coils wattmeters and take both readings. "1" to the line which yields the larger g and "2" to the line with the smaller g, measuring a load with lagging power This gives the phase sequence 1-2-3. h reference to Figures 1 and 2, the two eter readings are, in general

$$_{1}I_1 \cos(\theta_1 - 30°) \qquad (1)$$

$$E_{32}I_2 \cos(\theta_1 + 30°) \qquad (2)$$

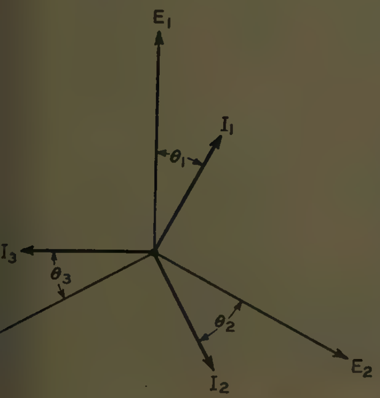
case of a balanced load, all values with pts equal each other, so that we obtain

$$I \cos(\theta - 30°) \qquad (1A)$$

$$EI \cos(\theta + 30°) \qquad (2A)$$

vever, the term cos $(\theta - 30°)$ is always ted with the current of the phase leads the other. We see that cos °) > cos $(\theta + 30°)$ in the range of lagging factor $90° > \theta > 0°$.

nany applications the line common to



2. Vector diagram of voltages and currents

the potential coils of the two wattmeters may not be denoted by "3" but from the equations a general rule can readily be set down.

Rule: For an inductive load the larger reading of the 2-wattmeter method belongs to the line number in the cyclical sequence 1-2-3 following the arbitrarily assigned line number common to the potential coils of the two wattmeters for the correct electrical phase sequence; for a capacitative load, the larger reading belongs to the line number preceding the line number common to the potential coils.

Tabulating the assigned line numbers under this rule for correct electrical sequences gives:

	Assign to Larger Reading	
	Inductive Load	Capacitive Load
Common Line	Line Number	Line Number
1	2	3
2	3	1
3	1	2

This rule has many applications, that is, it enables one to determine if a synchronous motor operates underexcited or overexcited if the phase sequence of the line is known. If the larger reading is measured in line 1 (line "3" common potential line), the motor is underexcited and vice versa.

MICHAEL A. TSCHUPP

(291 Devoe Street, Brooklyn 6, N. Y.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

INDUSTRIAL AND SAFETY PROBLEMS OF NUCLEAR TECHNOLOGY. Edited by M. H. Shamos and S. G. Roth. Harper and Brothers, New York, N. Y., 1950. 368 pages, illustrations, diagrams, charts, tables, $8^1/_4$ by $5^1/_2$ inches, linen, $4.00. Based on papers presented at a recent conference held at New York University, this book is devoted to the problems of the use of atomic energy. Part I considers details of the organization and operation of the United States Atomic Energy Commission. The fundamentals of nuclear physics, nuclear apparatus, the radiochemical laboratory, and industrial applications of radioactive isotopes are discussed in Parts II and III. Part IV deals with possible health hazards associated with the use of radioactive materials.

INGENIOUS MECHANISMS FOR DESIGNERS AND INVENTORS, Volume III. Edited by H. L. Horton. Industrial Press, New York, N. Y., 1951. 536 pages, diagrams, $9^1/_4$ by 6 inches, fabrikoid, $6.00. A companion to Volumes I and II of this series, this self-contained reference work is a part of a set which forms a comprehensive encyclopedia of mechanical movements. It contains illustrated descriptions of a large variety of standard and special mechanisms for use in designing automatic machines and other mechanical devices. Mechanisms of the same general type are grouped in chapters as in the previous volume.

INSTITUTE OF PETROLEUM ELECTRICAL CODE, Part I. Published by Institute of Petroleum, Manson House, 26 Portland Place, London, W. 1, England, 1950. 99 pages, tables, $9^1/_4$ by 7 inches, fabrikoid, ring binder, $9^1/_4$ by 7 inches, 26s. Prepared by a committee of experts, this loose-leaf compilation is the first part of a model code of safe practice for the petroleum industry. It carefully defines the circumstances in which special precautions should be taken, assesses and classifies the risks incident to various grades of petroleum and similar products, and develops effective methods of protection. The effects of static electricity are considered. The code ends with a series of rules of good practice.

INTRODUCTION TO MECHANICAL DESIGN. By T. B. Jefferson and W. J. Brooking. Ronald Press Company, New York, N. Y., 1951. 612 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $6.50. This textbook approaches the subject as a whole in the light of the functional purposes of a machine, its configuration requirements, economic considerations, the use of rational and empirical design data, and desired final appearance. Against this background is presented the elementary theory of machine elements, including a number of design considerations not usually covered in machine design texts. Although courses in the mechanics of materials and in the calculus are desirable prerequisites, they are not necessities.

LINES, NETWORKS AND FILTERS. By W. M. Breazeale and L. R. Quarles. International Textbook Company, Scranton, Pa., 1951. 293 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $6.50. Intended for use by third-year students who have finished a first course in a-c circuits and two years of college mathematics, this book is principally concerned with wire communication circuits. The first five chapters discuss in detail the general steady-state transmission-line relations. The next two are devoted to telephone lines and to ultrahigh-frequency and microwave line theory and practice. The theory of the exponentially tapered line is developed in the next chapter, and the last four chapters contain material on filters, matching networks, and equalizing networks. The rationalized meter-kilogram-second units are used throughout.

MATHEMATICAL ENGINEERING ANALYSIS. By R. Oldenburger. Macmillan Company, New York, N. Y., 1950. 426 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, cloth, $6.00. Intended for use as a text in courses on engineering analysis and industrial physics, this book is written to aid those who need to express physical situations in the form of equivalent mathematical relations. It develops the basic laws of engineering from a minimum number of assumptions so that the reader can obtain a logical physical and mathematical picture of the fundamental concepts of engineering in common use. With this as a background, the various techniques for making simplifying assumptions in treating physical problems then are illustrated. A knowledge of advanced calculus, especially those aspects concerned with line, surface, and volume integrals, is assumed.

MOTION AND TIME STUDY, PRINCIPLES AND PRACTICE. By M. E. Mundel. Prentice-Hall, New York, N. Y., 1950. 457 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $6.65. This book is intended to provide a systematic, practical, and scientifically correct treatment of present-day motion and time study. It considers the development and application of the basic principles of successful work. Illustrative examples from a wide variety of industries and types of work demonstrate the highly important reasoning process involved in the application of procedures. Graphic analyses are presented in the form in which they would normally appear in practice so as to provide a working guide.

N. F. P. A. INSPECTION MANUAL. Edited by H. Bond. National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass., 1950. 330 pages, illustrations, diagrams, tables, $6^3/_4$ by $4^1/_4$ inches, fabrikoid, $3.00. This pocket book covers the inspection work done for fire protection and prevention by property owners, fire departments, and inspection departments of various agencies. Replacing the book "Field Practice," this volume contains additional material on special hazards, building construction, and life safety.

ORDINARY NON-LINEAR DIFFERENTIAL EQUATIONS IN ENGINEERING AND PHYSICAL SCIENCES. By N. W. McLachlan. Oxford University Press, New York, N. Y.; Clarendon Press, Oxford, England, 1950. 201 pages, diagrams, charts, tables, $9^1/_2$ by 6 inches, cloth, $4.25. This book shows how certain types of nonlinear problems may be solved, and how experimental results may be interpreted by nonlinear analysis. It is chiefly confined to the presentation of various analytical methods employed in the solution of important technical problems. A wide variety of these is included, and practical details are given. References are given to sources of more rigorous theoretical treatments of the methods used.

QUANTUM MECHANICS. By A. Landé. Pitman Publishing Corporation, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 307 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $5.50. This book serves as an introduction to the subject and emphasizes the physical background of quantum mechanics and its close relation to classical experience. The principles of quantum mechanics are derived from a critical analysis of a few standard experiments. In a similar inductive manner, the technique of matrix mechanics is developed. Considerable space is devoted to nonconservative processes, and the Dirac electron and the elementary theory of radiation are considered. The last chapter deals with mesons. A bibliography of standard works is included.

RADIATION MONITORING IN ATOMIC DEFENSE. By D. E. Gray and J. H. Martens. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1951. 122 pages, illustrations, diagrams, charts, 8 by $5^{1}/_{2}$ inches, linen, $2.00. This practical working manual for radiological defense personnel provides full details on the use of all standard radiation detectors and the interpretation of their results. Brief background information is given on atomic energy, on radiation hazards, and on protective measures against atomic explosions. The book is intended for any one concerned with the measurement of radiation and requires no technical background to understand or use.

REFERENCE DATA FOR RADIO ENGINEERS. Third edition. Federal Telephone and Radio Corporation, an associate of International Telephone and Telegraph Corporation, New York, N. Y., 1949. 640 pages, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, fabrikoid, $3.75. Designed to fill a gap between textbooks and handbooks, this manual is a comprehensive compilation of basic electrical, physical, and mathematical data frequently needed in the solution of engineering problems. The third edition includes material expected to be of value to the engineer-in-training as well as to those in the fields of research, development, production, and operation.

(THE) SOLUBILITY OF NONELECTROLYTES (American Chemical Society Monograph Series 17). By J. H. Hildebrand and R. L. Scott. Third edition. Reinhold Publishing Corporation, New York, N. Y., 1950. 488 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $10.00. In this third edition, the comprehensive survey of the theory of nonelectrolytes is completely rewritten and expanded to over $2^{1}/_{2}$ times the size of the previous edition. New chapters deal with multicomponent systems, mixtures of gases, solid solutions, high polymer solutions, surface phenomena, and chemical equilibria and reaction rates. The treatment of metallic solutions is greatly extended. Still limited to a discussion of the equilibria involved in solubility, no consideration is given to rate processes in liquids and solutions.

SYMPOSIUM ON RAPID METHODS FOR THE IDENTIFICATION OF METALS (Special Technical Publication Number 98). American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 77 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $1.75. This symposium is a collection of methods and techniques of particular value in the field. The first three papers deal with the general principles of spot testing with chemical reagents, electro spot testing and electrographic analysis, and of modern instrumentation for the rapid identification of metals. The remaining six papers discuss specific applications of these methods or of combinations or modifications of them.

THEORY AND DESIGN OF INDUCTANCE COILS. By V. G. Welsby, with a foreword by W. G. Radley. Macdonald and Company, Ltd., 43 Ludgate Hill, London, E. C. 4, England, 1950. 180 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 18s. Of primary interest to the circuit designer, this book assists him in the selection of suitable coil designs. It shows how the performance of "inductors" can be related to their shape and size and the materials of which they are made. The methods of designing various types of inductance coils are illustrated by numerous examples. A short bibliography is included.

TRANSFORMER ENGINEERING. By the late L. F. Blume and Associates. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 500 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $7.50. This book is written to help engineers solve the technical problems arising in the specification, selection, application, and operation of transformers. Emphasis is placed on presenting the essential physics concerned in each problem, rather than a complete or exact mathematical treatment. In this second edition, compiled 12 years after the first, the major changes occur in the chapters on insulation, thermal characteristics, and the load ratio control problem.

TV MASTER ANTENNA SYSTEMS (Installation and Distribution). By I. Kamen and R. H. Dorf. John F. Rider Publisher, 480 Canal Street, New York 13, N. Y., 1951. 356 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $5.00. Designed as a working manual, this book discusses the installation and distribution, maintenance, usage, and merchandising of television master antenna systems. First individual-receiver antenna installations are considered. The largest part of the text is devoted to detailed expositions of important master antenna systems now in manufacture, complete with schematic diagrams, performance figures, and design data. The latter chapters deal with video distribution systems and general sales methods.

POWER SYSTEM STABILITY, Volume II. Power Circuit Breakers and Protective Relays. By E. W. Kimbark. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 288 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $8.00. This is the second volume of a 3-volume work intended for use by power-system engineers and by graduate students. The present volume covers power circuit breakers and protective relays, including material on rapid reclosure of circuit breakers and on the performance of protective relays during swings and out-of-step conditions. Both 3-pole and selective-pole tripping and reclosure are discussed. Numerous references and a set of problems are included at the end of each chapter.

PRINCIPLES OF ELECTRICAL ENGINEERING, THEORY AND PRACTICE. By G. C. Blalock. Third Edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 605 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5.50. Serving as a textbook for nonelectrical engineering students, this book presents fundamental principles in concise form with frequent references to practical applications. In this third edition, the author has amplified and modernized the text. A new chapter on dielectric fields and circuits is added. The superposition, reciprocal, and Thévenin theorems are added to a later chapter, and the treatment of both d-c and a-c networks is expanded considerably. The chapter on electronics is enlarged and amplified both as to theory and practical applications.

REGELTECHNIK. By K. Seidl. Franz Deuticke, Vienna, Austria, 1950. 68 pages, diagrams, charts, tables, $9^{3}/_{4}$ by $6^{1}/_{2}$ inches, paper, $1.70. This book explains the principles of various types of automatic control equipment as used in power stations; conveyor systems; automatic drives for cars, ships, and airplanes; the control of gas pressure and flow, and so forth. It covers the fundamentals and theory of control and regulating equipment, the characteristics of different types of control mechanisms and circuits, and the underlying mathematical principles.

TRAVELING WAVES ON TRANSMISSION SYSTEMS. By L. V. Bewley. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 543 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $12.00. This book is a collection of the modern theories of transient voltage phenomena on electric power transmission lines and in transformer windings. Special emphasis is placed on the use of these theories in the design of lightning-proof transmission lines. The present edition is enlarged by half to include new developments in the field and to include problems at the end of the chapters. A working knowledge of operational calculus is assumed.

VOLTAGE STABILIZERS. By F. A. Benson. Published by Electronic Engineering, 28 Essex Street, Strand, London, W. C. 2, England, 1950. 125 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, linen, 12s.6d. Based on a series of articles published in "Electronic Engineering," this monograph reviews methods of stabilizing voltages and contains much data which have been published only in the various scientific periodicals. Three main methods of stabilizing voltage, that is, magnetic saturation, glow-discharge tubes, and thermionic tubes, are discussed in detail in separate chapters.

PAMPHLETS • • •

**The following recently issued pamphlets may
interest to readers of "Electrical Engineering
inquiries should be addressed to the issuers.**

**Industrial Utilization of Fission Produ
A Prospectus for Management.** The
ford Research Institute has made a stu
the possible industrial uses that can be
of atomic by-products. The scope an
jectives of the study program are desc
in detail in this booklet which was pre
under contract to the Atomic Energy
mission's Division of Reactor Develop
The properties, availability, cost, and
ble uses of fission products are the pri
subjects covered. Copies can be obt
from: Project 361, Department of Bu
and Industrial Economics, Stanford Res
Institute, Stanford, Calif.

**American Standard for Brushes for
trical Machines.** The standard co
definitions, dimensions and tolerances
test procedures needed for the manufa
and use of these brushes. Definition
given for five types of brushes—carbon
bon-graphite, electrographitic, graphite
metal-graphite. Brushes also are cla
and defined into three groups—frac
horsepower, industrial, and split br
Diagrams illustrating various type
brushes, their corners, ends, edges,
shoulders, are included. Shunt termin
brushes to be used in reaction or bo
holders are also illustrated in the star
An appendix at the back contains a
design data form sheet. Copies o
standard, *C64-1-1950*, may be obtained
the American Standards Association, 7
45 Street, New York 17, N. Y.

**Safety Manual for the Die Casting I
try.** Prepared by the American Die C
Institute, this is a comprehensive cover
all departments, operation, and proce
An appendix contains blueprints of
devices, typical record and report form
a complete list of safety organization
books, and periodicals. Illustrated.
are available from the American Die C
Institute, Inc., 366 Madison Avenue
York 17, N. Y., for $5.00 a copy.

**Manual on Quality Control of Mat
Prepared by the American Society fo
ing Materials (ASTM), it takes the p
the ASTM Manual on Presentation of
The new manual is organized into
parts. Part 1 essentially covers the pre
tion; Part 2 presents limits of uncerta
an observed average; Part 3 explai
control chart method of analysis and m
for presentation of data. The 10
booklet can be obtained from the Am
Society for Testing Materials, 1916
Street, Philadelphia 3, Pa., at $1.75 pe

Infrared on the Farm. This book
plains how infrared heat lamps can h
crease farm productivity. It descri
use of infrared radiant heat in
drating meats, vegetables, fruits, and
For a copy write the Advertising an
Promotion Department, Westinghouse
Division, Bloomfield, N. J.

t's a fact that

- ✓ Some of the very low expansion AlSiMag Ceramics have excellent heat shock qualities and can be heated red hot and suddenly cooled without damage.
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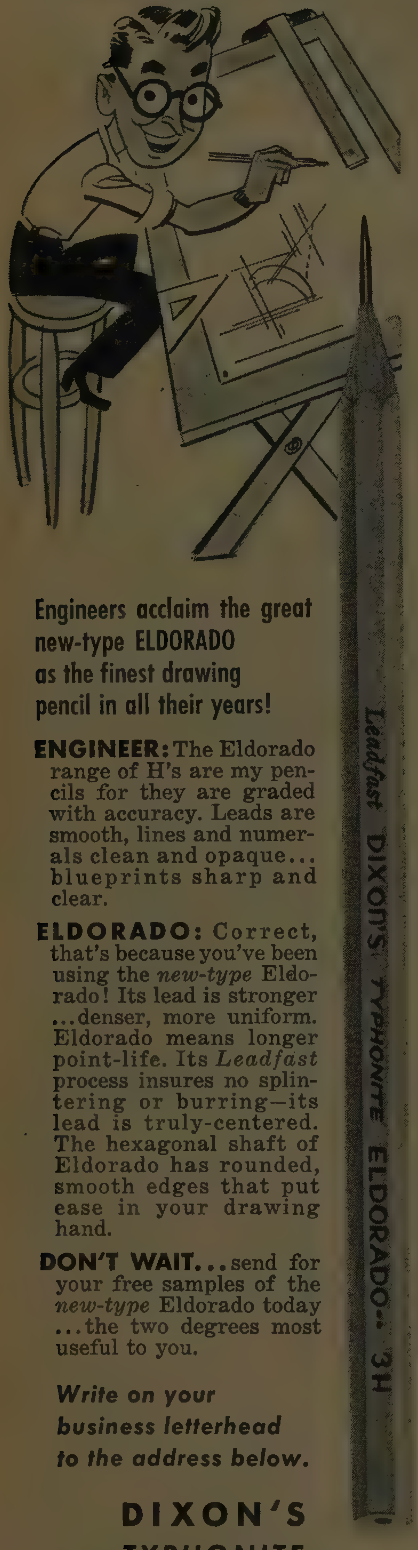
W ENGLAND, 38-B Brattle St., Cambridge, Mass., Kirkland 7-4498 • ST. LOUIS, 1123 Washington Ave., Garfield 4959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INDUSTRIAL NOTES ....

A $2,800,000 Expansion Program is Launched by Carboloy. In order to meet a rapidly increasing demand for tungsten carbides, the Carboloy Company, Inc., a General Electric affiliate, has launched a $2,800,000 plant expansion program. Of the total, approximately $800,000 is being devoted to expanding the present Carboloy plants in Detroit, Mich., while $2,000,000 is for constructing and equipping a new plant in Edmore, Mich.

U. S. Steel Elects New Director. The United States Steel Corporation has announced the election of Herbert E. Smith as a Director of the corporation and a member of its Finance Committee, succeeding the late Robert C. Stanley.

Ohio Brass Appointments. The Ohio Brass Company has appointed Joseph B. Doran and William E. Morrison district managers in the Eastern territory, with headquarters in New York City.

Sylvania Purchases Continental Can Building; Appointments. Sylvania Electric Products, Inc., has purchased the Continental Can Company building in Wheeling, W. Va., where it will manufacture fluorescent lighting fixtures. The company has also announced the appointments of D. W. Gunn as equipment sales manager, and G. V. Bureau as government sales manager.

Alcoa Appointment. Lewis P. Favorite has been named manager of the Aluminum Company of America's New York district sales office.

Uptegraff Manufacturing Appoints Pittsburgh District Manager. R. E. Uptegraff Manufacturing Company has announced the appointment of H. W. Petty as manager of the company's newly opened Pittsburgh sales office.

Lear Elects Vice-President. Albert G. Handschumacher has been elected a Vice-President of Lear, Inc. Mr. Handschumacher will assume the responsibilities of assistant general manager of the company and relinquish his post as assistant to the president.

Westinghouse News. The Westinghouse Electric Corporation has purchased land in Farmers Branch, Tex., for construction of a light-bulb warehouse. Completion is scheduled for the summer of 1951. The corporation also has announced plans for construction of a headquarters plant and engineering laboratories for their new electronic tube division in Elmira, N. Y. The plant will produce electronic tubes for the military services and for defense industries.

Westinghouse also has announced the appointment of E. D. Delano as manager of the New England district, with headquarters in Boston, Mass., succeeding L. E. Lynde, newly elected Vice-President, who will have charge of the company's government activities in Washington. Other appointments are: Dr. Rolland M. Zabel, manager of engineering, Westinghouse lamp division; Dr. S. W. Herwald, manager, engineering development division; P. L. Fosburg, manager, design section; N. V. Petrou, manager, computing devices section; R. E. Span, manager, analytical section; C. E. Bagwell, manager, autopilot section; G. F. Towner, manager, turret systems section; H. D. Lawton, supervisory engineer in charge of design work on fixed gunfire control systems; Harry D. Hanafus, purchasing agent, electronic tube division; Harry F. Blythe manager of accounting, tube division W. H. Dickinson, director, manufacturing division, Engineering Department; G. P. Longabaugh, director, headquarters manufacturing division, Equipment Department; and George S. Evans, manager, commercial engineering, Lamp Department.

Allis-Chalmers Appointments. Gerald E. Smart has been named plant engineer, assisting J. J. De Windt, general superintendent of maintenance, time study, and tool design, at the Allis-Chalmers Manufacturing Company's Norwood (Ohio) works. Dwight H. Lory has been appointed to the Electrical Sales and Engineering Department at the Norwood works. Allis-Chalmers has also announced the appointments of nine new sales representatives; those named and the district offices to which they have been assigned are: John W. Becker, Syracuse; Joseph L. Luber, Washington, D. C.; Joseph M. Duncan, Atlanta; Charles C. Leach, Philadelphia; Floyd Blackwell, Jr., Chattanooga; David C. Emery, Cleveland; William V. Glasser, Omaha; James R. McCausland, St. Louis; and John Rayburn, Amarillo.

Marcus Transformer Appoints New Sales Representative. W. D. Evan, Jr., Pacific Industries, 1045 South Olive Street, Los Angeles 15, Calif., has been appointed sales representative for the Marcus Transformer Company of Hillside, N. J. Mr. Evan succeeds Robert Young and Company.

RCA Victor Names Seven Product Managers. The RCA Victor Division of the Radio Corporation of America has announced the appointment of seven product managers in the company's newly organized product administration division. The new product managers are: E. E. Minett, research product section; A. C. Lindquist, communications product section; M. A. Trainer, broadcast product section; R. A. Teare, theater, visual, and sound products section; M. S. Klinedinst, industrial product section; H. W. Hucke, product coordination section; and R. H. Holmes, contract administration section.

(*Continued on page 22A*)

High among the advantages of Stackpole Silver Tungsten Contacts is the fact that they stand up well under corrosive atmospheric conditions. Salt air, high humidity, sulfide atmospheres and similar adverse conditions do not affect this material to the extent that they do many other refractory contact materials.

Probably no other contact material does a better job of assuring low contact resistance in continued operation where heavy arcing is present or under closed conditions. Stackpole silver tungsten contacts are made in practically any desired shape or size and in grades specifically "tailored" to your application.

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HANDY CONTACT DATA

Stackpole booklet No. 12 contains a wealth of data to help solve your contact problems. Write for your copy today.

**ELECTRICAL BRUSHES (All carbon, graphite, metal and composition types) • RARE METAL CONTACTS
WELDING RODS, ELECTRODES and PLATES • BRAZING BLOCKS • RHEOSTAT PLATES and DISCS
PACKING, PISTON and SEAL RINGS • CARBON REGULATOR DISCS • SINTERED IRON COMPONENTS
and many other items.**

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TRANSFORMERS

Dry-Type

for Every Purpose

¼ to 1000 Kv-a. Single phase
1 Kv-a. to 2000 Kv-a. 3-phase

To operate 115 volt lighting and portable equipment from 230, 460 or 575 volt power circuits.

To operate special equipment from standard circuits.

To change odd voltages to standard voltages, and phase changing.

For indoor installations without fire-proof vaults

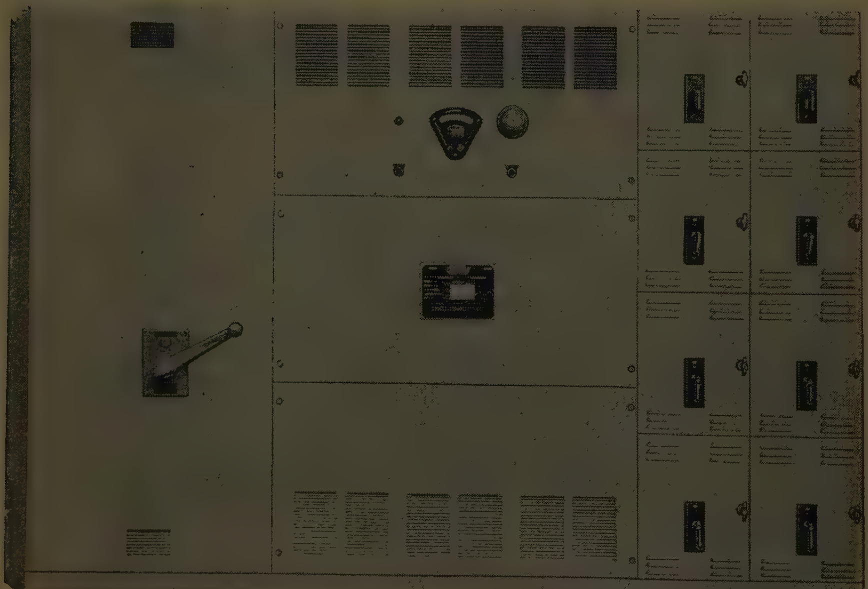
¼ Kv-a. Single Phase
460/230 to 230/115 volt

15 Kv-a. 3-phase
Wall mounting type.
Showing connection
compartment with
solderless terminals

Unit Sub-Stations

For interior high voltage distribution systems with transformers at load centers.

Sizes up to 2000 Kv-a. and up to 15,000 volts.



2000 Kv-a. 12,000 volt sub-station, with primary fused load interrupter switch, temperature indicator and alarm, and extra contacts that may be used to operate forced draft fans to increase capacity 25%

Sales Engineers in Principal Cities

Sorgel Electric Co., 846 W. National Ave., Milwaukee 4, Wis.

Pioneers in the Development and Manufacturing of Air-Cooled Transformers

(Continued from page 18A)

Hinck Heads Du Mont Compon
Sales. Edwin B. Hinck has been m
sales manager of the electronic p
division, Allen B. Du Mont Laborato
Inc. Mr. Hinck succeeds Harry V
Rensselaer, who has been recalled by
United States Air Force.

G-E News. The General Electric C
pany has appointed L. T. Callahan ma
ger of operations of their aircraft
turbine divisions; W. G. Arnold, mana
of manufacturing, Welding Departme
G. P. Foster, district representative
2-way communications equipment, c
mercial equipment division; and Rol
R. Person, staff assistant to the mana
of manufacturing, large apparatus d
sion, and secretary of the division's app
priation committee.

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Leak Detector. Operating on the p
ciple that the tendency of hot platinum
emit positive ions is stimulated enormo
by infinitesimal traces of halogens or t
compounds, a new and extremely sensi
leak detector for use in vacuum syst
down to a pressure of one micron
mercury has been announced by Dist
tion Products Industries, Division
Eastman Kodak Company. In operat
the glass sensitive tube of the leak detec
model *LD-01*, is sealed into the sys
under test and the system then is pum
down to a moderate vacuum. A jet
harmless Freon gas, or other halog
contained gas (in small cylinders), the
directed against portions of the sys
suspected of leaking. When the jet str
a leak there is a sudden deflection of
meter needle on the instrument face
cause the gas—entering the system
instantly increases the ability of a
platinum anode in the sensitive tube
emit positive ions. Further informat
on the detector may be obtained fr
Distillation Products Industries, Roches
N. Y.

Mechanical Failures Forecast by Coat
Process. A testing process which
forecast weeks and months in adva
where failure will occur in an airpl
engine or other mechanical products
been developed by the Magnaflux C
poration, 25 West 43rd Street, New Y
18, N. Y. The test involves the use of
extremely brittle material known
Stresscoat which is sprayed on the p
to be tested. When the test part is s
jected to the same kind of load it
undergo in service, the metal deforms
stretches slightly in an amount prop
tional to the load. The brittle coati
however, will not stretch, and cracks
glass at the points where the strains
heaviest. The coating can be made
crack when the metal beneath it is
formed as little as 0.0001 inch per inch
length. Metal parts fail from fatigue

(Continued on page 28A)

The ADVANCED DESIGN FEATURES of the

KEARNEY 200 AMPERE Type "T" TRIP-OUT

Assures You of

Better Protection

of Equipment on Lines Up to 15,000 Volts

Here's why-

- Silver to silver contacts for heavy loads
- High conductivity copper current path through switch
- Floating top contact to assure proper contact alignment
- Fuse cartridge opens at both ends — assures rapid expulsion of arcing gases and high interrupting capacity
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Here, in a versatile instrument of advanced design, are all the things you need for complete oscillographic recording. The Hathaway Type S-8 Oscillograph, which has long been the standard of oscillographic recording, has been improved to meet the rapidly expanding demands of modern research. Whether your measurement problems are simple or complex, the NEW Type S-8 Oscillograph has the inherent capabilities necessary to measure vibration, pressure, acceleration, and strain with new ease and accuracy.

The newest features include:

QUICK-CHANGE TRANSMISSION *fully enclosed with gears running in oil* to provide instantaneous selection of 16 record speeds over the range of 120:1

CHART TRAVEL INDICATOR provides continuous indication of chart motion. Operator knows instantly by flashing lamp if anything should happen to interfere with chart motion

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NEW GALVANOMETER STAGE accommodates *all* Hathaway galvanometer for recording milliamperes, microamperes, or watts

NEW RECORD-LENGTH CONTROL AND NUMBERING SYSTEM designed for long, trouble-free service under all kinds of ambient conditions

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WIDE RANGE OF GALVANOMETER TYPES AND CHARACTERISTICS provide for almost any recording requirements. Natural frequencies to 10,000 cps. Sensitivities to 50,000 mm per ma, single and polyphase watts

DAYLIGHT LOADING AND UNLOADING RECORDS TO 200 FT. IN LENGTH, width to 10 inches

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12 TO 92 ELEMENTS

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(*Continued from page 22A*)

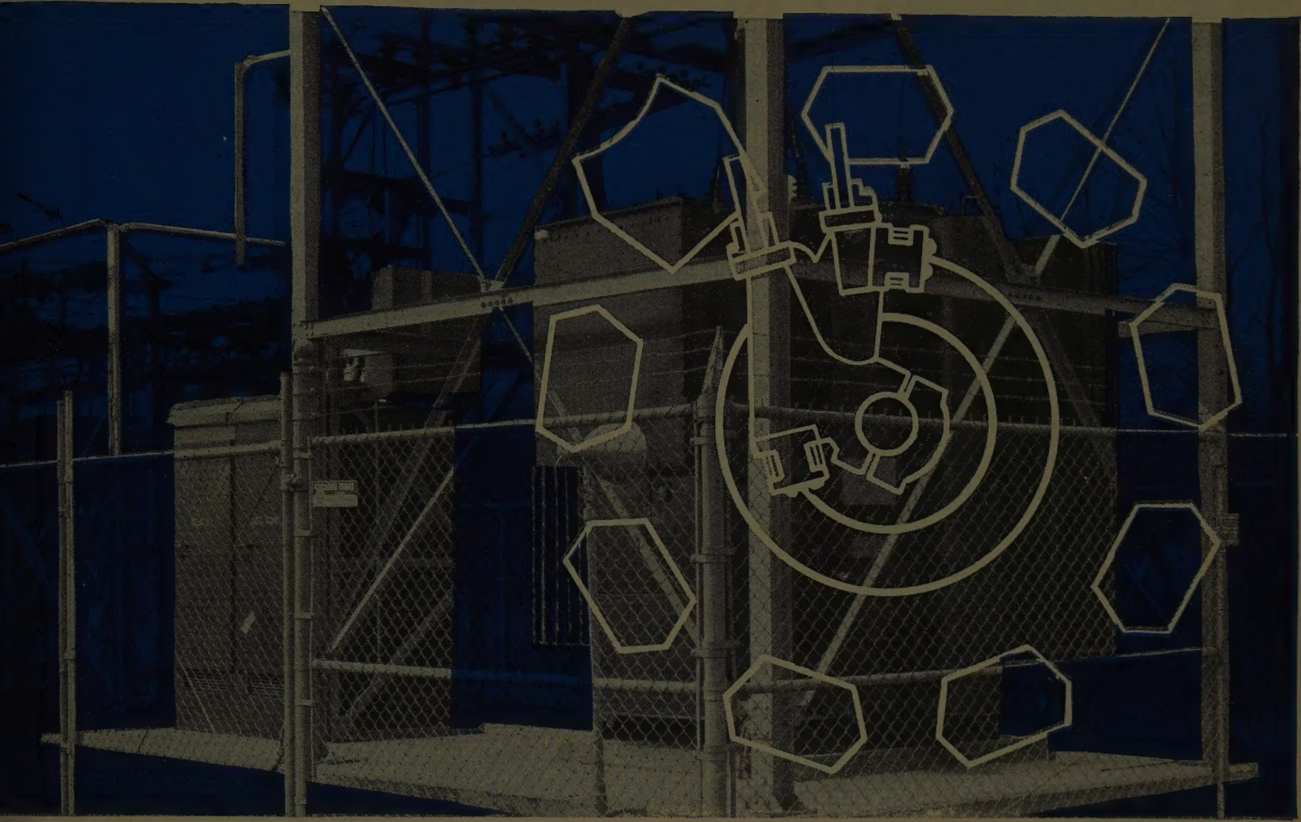
service after being subjected to the sam load millions of times. Stresscoat fail the first time the load is applied, in th same place where the part will eventuall fail in service. At present the coating is being used in testing of aircraft engin connecting rods, wings and structura parts, and critical components of differen mechanical products. Further information on this coating is available from th Magnaflux Corporation.

Resistance Thermometer. Designed t overcome problems faced in making correc temperature readings of stored petroleum products, the Weston model *918* averagin resistance thermometer can be installe for use in existing tanks without takin the tank out of service. Accurate average temperature readings to within one-hal degree Fahrenheit can be made regardless of the product, product level, and temperature gradient of the product in the tank Readings can be obtained in a few second as compared to the long necessary immersion time for cup case thermometers. Th Weston model *918* consists of a flexibl resistance bulb assembly, a meter, and a oil level selector, with the meter an selector enclosed in a meter housing fo protection, while the bulb assembly is placed permanently inside the tank. The assembly operates on six direct volts, which may be supplied by dry cells or fro a 115-volt a-c circuit by equipping th meter with a transformer and rectifier. Additional information may be obtained from the Weston Electrical Instrument Corporation, 641 Frelinghuysen Avenue, Newark 5, N. J.

Electronic Combustion Safeguard. A new electronic combustion safeguard system for commercial oil burners, which provides immediate cutoff of fuel in case of failure, has been announced by the General Electric Company's Control Divisions. The system, which includes a switch-amplifier-contactor unit, phototube holder, and electrode holder, assures protection against combustion failure because: (1) if the gas pilot does not ignite, the oil valve cannot open; (2) if the oil flame does not ignite, the supply of fuel is cut off. After the cutoff, the motor continues to operate for 30 seconds to purge the nozzle or cup of unburned fuel to prevent carbonizing and reduce field servicing. The system then is locked against further operation until manually reset. Upon resumption of service following a power failure, low water cutoff, or limit control operation during the starting cycle, the oil valve cannot open until the program switch recycles. When continued operation of the burner is prevented by ignition failure, a positive lockout mechanism is actuated and a light on the cabinet cover indicates that the equipment has gone to lockout. Operation cannot then be resumed until the rese button is pushed. A self-checking circui prevents starting of the equipment unles the photoelectric detector, pilot protector

(*Continued on page 48A*)

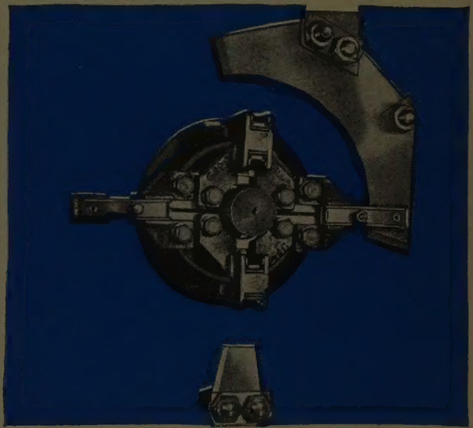
ELIMINATE ALL ARCING
N TAP SELECTOR SWITCH CONTACTS WITH . . .



, MOLONEY LOAD TAP CHANGERS PROVIDED ON FEEDER VOLTAGE REGULATORS, GULATING TRANSFORMERS, LOAD RATIO CONTROL TRANSFORMERS

Moloney Feeder Voltage Regulators, Regulating Transformers Load Ratio Control Transformers are provided with Load Tap ngers which feature a load transfer switch to relieve the tap ctor switch of all arcing duties. The load transfer switch has only stationary contact tips per phase as compared with eighteen on ap selector switch. This arrangement not only reduces the number ontacts subject to arc erosion, but also permits longer arc clear- s to assure positive break of the arc. Liberal clearances of current ying parts result in maximum capacity of the regulating equipment minimum physical size. The load transfer switch, which is the switch required to transfer load current, is provided with ac- rating springs and is driven by Geneva gears. This assures quick k of the arc.

is but one of the many features of the Moloney Load Tap Changer. same sound basic construction is found in the regulating appa- on which the tap changer is used.



Liberal clearances prevent establishment of an arc between adjacent current carrying contacts of the load transfer switch. Special alloy arcing tips prevent damage to the switch contacts as they are opened or closed.

ME81-10

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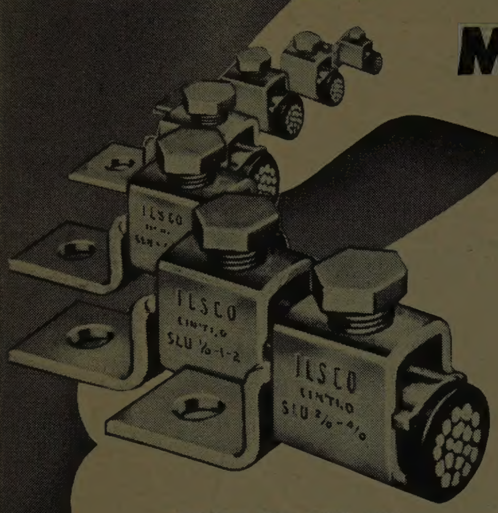

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ELECTRICAL ENGINEERS: MAKERS OF ELECTRICAL COILS AND INSULATION— REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES
TRADE MARK

(Continued from page 28A)

and electrode are in proper operati condition. The motor circuit is controll directly by the built-in contactor for mot ratings up to and including one-half hor power, 110 to 120 volts, single pha Further information is available from t Apparatus News Bureau, General Electr Company, Schenectady 5, N. Y.

Aperiodic Power Amplifier. T General Radio Company, 275 Mass chusetts Avenue, Cambridge 39, Mas has developed a power amplifier, ty *1233-A*, with three output combination (1) 20 cycles to 20 kc, into 150 or 6 ohms balanced or grounded. On th range, an output of 15 watts is availab between 50 and 15,000 cycles; (2) kc to 1.5 megacycles into 50 ohms, balanc or grounded. Maximum output is watts from 20 kc to 0.5 megacycle; watts at 1.5 megacycles; and (3) cycles to 3 megacycles. Output is 1 volts peak-to-peak, for a high-impedan load with a gain of 60 decibels. Wi grounded output, voltage is limited to volts, peak-to-peak, with a gain of decibels. Rise time is approximately 0 microsecond, with negligible overshoo Maximum output is obtained in all cas with an input of 0.2 volt. Distortion below three per cent at maximum outp over most of the frequency range, and noi is between 60 and 70 decibels below watts. In addition to its use as a gener laboratory or testing amplifier, type *1233-* has applications in the driving of supe sonic generators, the exciting of broadca antennas for measurements with deflectio type instruments, and for use as an oscill scope deflection amplifier. When us with an antenna and tuned input it c drive a modulation monitor to monit remote transmitters. Additional deta may be obtained from the General Rad Company.

Liquid Fire Extinguisher. A new on gallon vaporizing liquid fire extinguish named the Air-Flo has been developed the Buffalo Fire Appliance Corporatio Dayton, Ohio. It operates on an entire different principle in that dual air pump build up internal air pressure which i stantly forces the liquid out in a co tinuous steady stream up to 30 feet. offers effective protection against electric and flammable liquid fires. Intern corrosion is prevented by a new dryi liquid, Dryex. Further information available from the company.

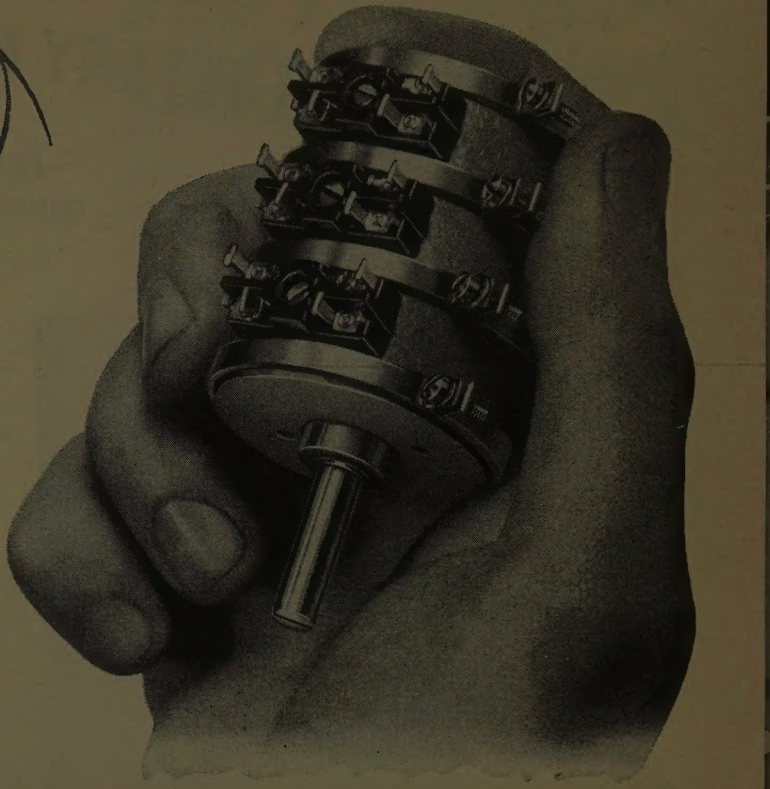
Civil Defender Radio. A special fr quency-modulated radio receiver for u by civil defense organizations having 2-w radio systems at their command has be announced by the General Electric Com pany. It is called the Civil Defende The new receiver can be used by poli agencies, fire departments, water depa ments, the Red Cross, and other grou comprising the civil defense organizatio A novel feature of the unit allows ci

(Continued on page 52A)

ere's Fairchild's Newest Potentiometer!

TYPE-746
PRECISION POTENTIOMETER OFFERS:

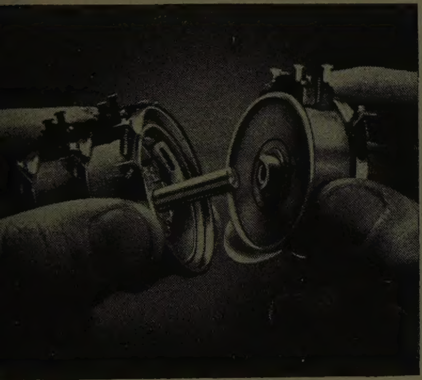
- Low Torque
- Accurate Phasing
- Quick Replacement
- Ganging up to 20 on a shaft



e finest we've ever built! That's our idea the new "746". It's got lower torque, ew more accurate phasing adjustment, a new method of ganging that makes it y to put as many as twenty cups on a gle shaft. Individual cups in a gang are ily replaced if necessary.

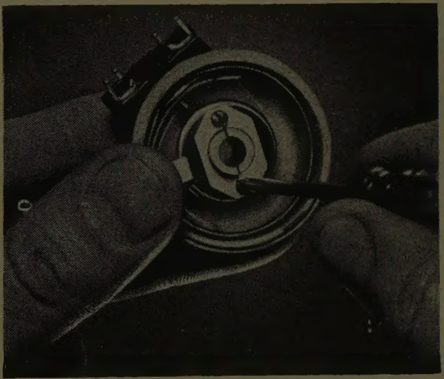
The new potentiometer is available with ear or non-linear windings to meet your cifications. Its attractive case is made of y anodized aluminum.

The "746" is just one of the complete Fairchild nily of precision potentiometers. What are your uirements? Write, giving details, to *Fairchild nera and Instrument Corporation, 88-06 n Wyck Boulevard, Jamaica 1, N. Y.* Dept. 140-13L1.



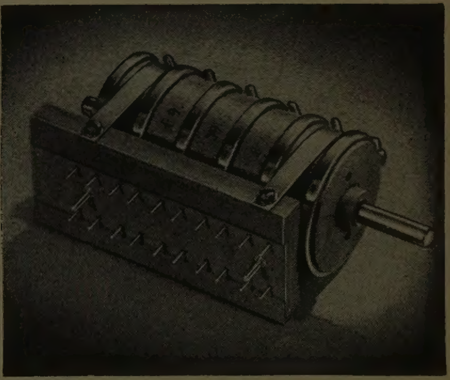
EASY REPLACEMENT

replace a unit in a "746" gang, loosen con-ting-band screws, remove "cup," slip new p" under bands, and tighten screws. This ture pays off in experimental work where uit elements are changed periodically.



ACCURATE PHASING

A new type phasing adjustment is simpler and more accurate. A retainer plate clamps shaft to wiper arm. To adjust for phasing, loosen two screws, set the arm to the correct position, then tighten screws.



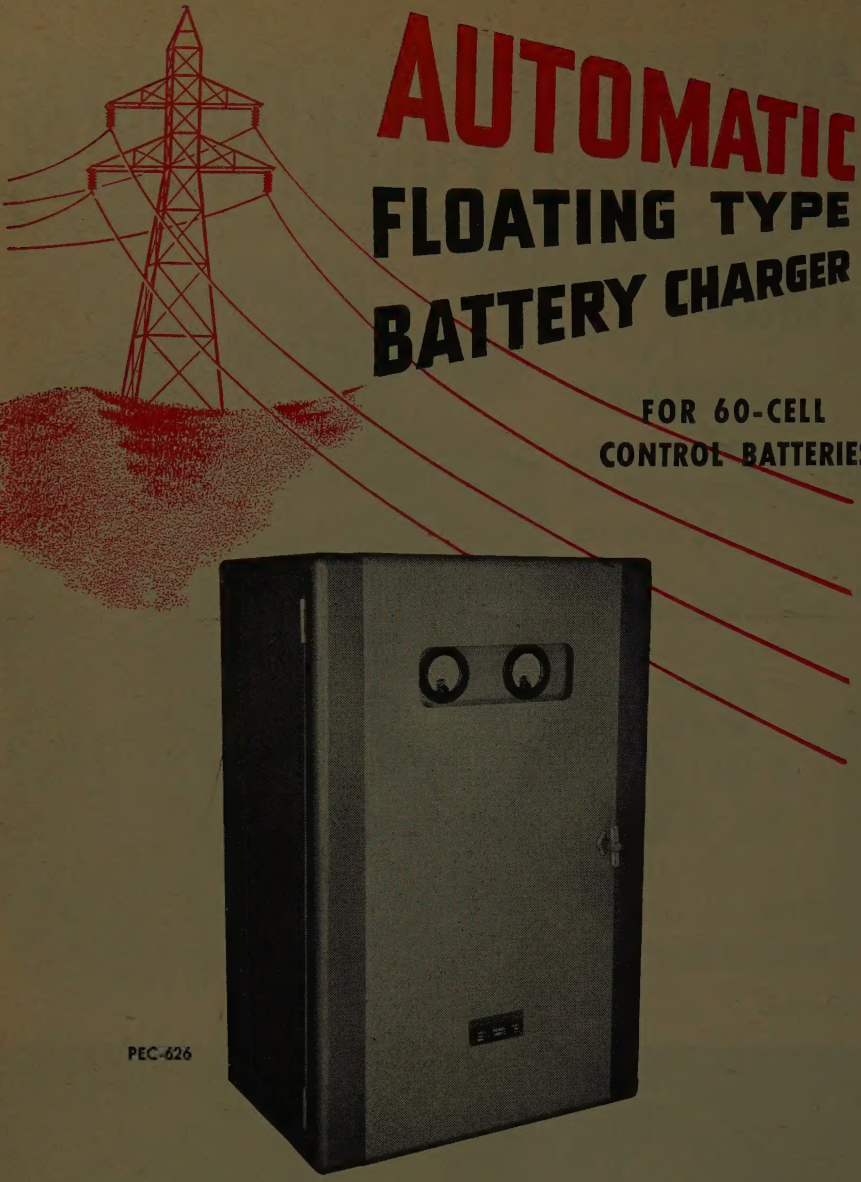
FLEXIBLE DESIGN

Typical of the special consideration Fairchild gives to its customers' special requirements is this plug-in version of the "746." Where fast servicing is a must, the advantages of this "quick-change" unit are quite apparent.

SPECIFICATIONS

ccuracy (overall resistance)—±.5% (linear), ±1.0% or better (non-linear)
echanical accuracy—
concentricity (shaft to pilot)—.0015 in. FIR max.;
radial play—.0009 in. FIR max.;
shaft—centerless ground stainless steel to .2500 diam. (+.0000, —.0005 in.);
pilot hub—machined to .5000 (+.0000, —.0005 in.)
orque—1.5 oz-in.
imensions—diameter 1.750 max.; length (1 cup) .800 in. ±.009 in.; added length per unit ganged .580 in. ±.002 in.
ase—grey anodized aluminum

FAIRCHILD
PRECISION POTENTIOMETERS



AUTOMATIC FLOATING TYPE BATTERY CHARGER

FOR 60-CELL CONTROL BATTERIES

...gives you extreme accuracy and exceptional reliability

EXPRESSLY DESIGNED for unattended station service, the PEC-626 Automatic Battery Charger provides the extreme accuracy of electronic control plus the exceptional reliability demanded by this type of service.

In designing this unit, Power Equipment Company engineers started with the rugged components of a manual charger, added a magnetic system for coarse voltage control, then a simplified electronic system for fine voltage control.

The PECO Charger accurately floats the control battery of any power station or substation which has a reasonably constant switchboard load; furnishes power to the load and maintains a fully charged battery, ready for any emergency. DC output is sufficient to continuously charge 60 lead acid battery cells at 129 volts, at a maximum rate of 12 amperes, and is automatically regulated to within ±0.5 percent, for AC line voltage fluctuations of ±5 volts on a 230 volt circuit.

Exceptional reliability is shown by the fact that if the electronic control section should be disconnected, the magnetic control section will still automatically hold the output voltage to within ±3 percent of nominal voltage.

Write for specifications now!

POWER EQUIPMENT Company

Battery Chargers ☆ Battery Eliminators ☆
D.C. Power Supply Units ☆ Regulated Exciters
☆ and other Special Communications Equipment

55 ANTOINETTE ST. DETROIT 2, MICHIGAN

(*Continued from page 48A*)

defense headquarters to broadcast messag
to all groups at once, or to separate grou
individually. Each receiver is inacti
until turned on by headquarters. I
addition to receiving messages from head
quarters, it can be used to automaticall
start and stop air raid sirens or othe
warning devices. The push of a butto
at headquarters broadcasts a special ton
which, when received by the Civil De
fender, operates a switch to activate th
warning device system. When a messag
is received, a lamp lights on the receive
and remains lighted until turned off b
the operator. Should he be away fron
the receiver, and upon returning see th
lighted lamp, he would know a messag
was broadcast, and could check wit
headquarters. Two models are available
one will operate in the 30- to 50-megacycl
band of the radio-frequency spectrum, an
the other will operate in the 152- to 17
megacycle band. Both are designed t
operate on standard 117 alternatin
volts. However, an inverter will be mad
available to permit operation from
6-volt storage battery. The receiver
are double conversion, superheterodyn
types, with two separate crystal-controlle
oscillators. Further information is avai
able from the General Electric Compan
Electronics Park, Syracuse, N. Y.

TRADE LITERATUR

Planned Lighting. "Planned Lightin
for Industry" is the name of a comprehen
sive 47-page publication issued by the eng
neering division of General Electric's Lam
Department. Designated bulletin *LD-*
it describes how to engineer lighting t
various industrial tasks, discussing six prin
cipal lighting systems and the use of sp
cific techniques for special needs. Sing
copies of *LD-4* are available through th
Inquiry Bureau, Lamp Department, Gen
eral Electric Company, Nela Park, Clev
land 12, Ohio.

Precision Test Equipment. The Poly
technic Research and Development Com
pany has published a new 67-page cata
logue, which contains descriptions of the
test equipment. The catalogue is availab
from the company at 202 Tillary Stree
Brooklyn 1, N. Y.

Air-Conditioning Guide. A plannin
guide for industrial air conditioning, boo
let *B-5160*, has been announced as availab
from the Westinghouse Electric Corpor
tion, Sturtevant Division, 200 Readvil
Street, Hyde Park, Boston 36, Mass.

High-Speed Motion Picture Camera
Wollensak Optical Company, Industri
and Technical Division, has issued a cat
logue containing information, specifica
tions, and applications of the 8-, 16-, an
35-millimeter Fastax high-speed motio
picture cameras and the 16-millimeter o
cilloscope camera. The catalogue may
obtained from the company at Rochest
21, N. Y.